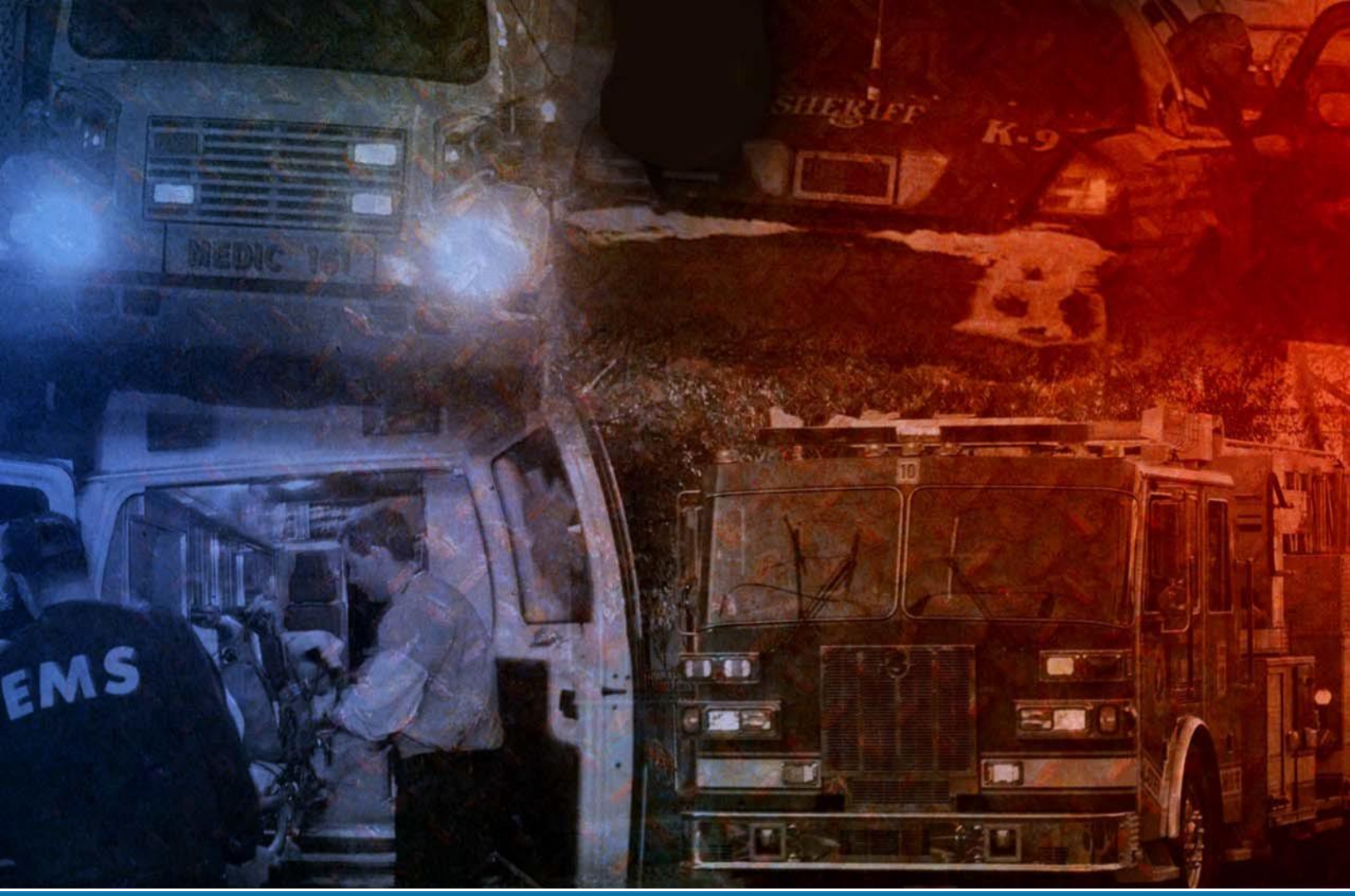

COMPREHENSIVE TESTING OF IMMINENT THREAT PUBLIC MESSAGES FOR MOBILE DEVICES: UPDATED FINDINGS

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COMPREHENSIVE TESTING OF IMMINENT THREAT PUBLIC MESSAGES FOR MOBILE DEVICES: FINAL REPORT

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Executive Summary

This project sought to determine the *optimized message content* of imminent threat messages delivered over the Wireless Emergency Alert (WEA) Service should the length of future WEA messages be expanded from 90 to 280 characters. Previously, the research team conducted interview, focus group, experiment and survey research on the optimized message content of 90-, 140- and 1,380-character messages (Bean et al., 2014).[1]

This prior research found that 1,380-character messages appeared to produce optimized interpretation, personalization, and information seeking and sharing outcomes, and would likely yield maximized public protective action-taking behavior. Shorter messages that were 90- and 140-characters appeared less effective at guiding people toward protective action-taking, but these messages were rapidly distributed and quickly reached a large percentage of at-risk populations.

Given these prior findings, the research presented in this report investigated the following questions through six focus groups and eight experiments with the public:

1. Are 280 character WEA messages more effective than 90-character messages, and what is the best way to optimize character length should future WEA messages expand from 90 to 280 characters?
2. What is the best way to optimize maps, should future WEA messages have the capacity to include maps along with WEA messages, and what are the potential unintended consequences of including maps?
3. What is the potential added value (vs. unintended consequences) of including hyperlinks (i.e., web addresses) with additional general or static imminent threat information should future WEA messages have the capacity to do so?
4. What is the potential added value (vs. unintended consequences) of providing mobile applications (apps) with additional personalized or dynamic imminent threat information, either along with a future WEA message or as a stand-alone product?
5. Do the findings generalize across hazards?

We selected 280-character messages for testing and comparison to 90-character messages based on industry and stakeholder feedback, and because 280-character messages are the maximum length that current "smart" phones can display in a single screen.[2] Focus group and experiment research presented in this report led to the following conclusions and recommendations regarding 280-character messages:

Message content order. Moving the source to the start of a WEA message is optimal; however, the optimal order for all WEA message content seems to depend on message length.

Message source. Local sources may not always be the best sources. Instead, well-known federal sources such as the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS) can be just as, if not more, effective.

Map elements. None of the map elements tested had a statistically significant effect on message outcomes, and research participants varied widely in their reactions to the tested maps. Maps can be useful in message

[1] Bean, H., Liu, B., Madden, S., Mileti, D., Sutton, J., & Wood, M. (2014). *Comprehensive testing of imminent threat messages for mobile devices*. Retrieved from http://www.firstresponder.gov/TechnologyDocuments/Comprehensive%20Testing%20of%20Imminent%20Threat%20Public%20Messages%20for%20Mobile%20Devices.pdf.

[2] The Communication, Security, Reliability, and Interoperability Council (CSRIC), a working group sponsored by the Federal Communications Commission (October 17, 2014), recommended testing 280-character messages as the potential length for future WEAs.

personalization, but the role they play varies based on message length.

Relative importance of content elements. The message elements of guidance (what to do and how to do it) and time until impact (how much time people have to take the recommended action) play major roles relative to other message elements in impacting the outcomes of public understanding and belief of the protective action recommendation, as well as the ability to decide how to respond.

Generalizing across hazards. Like shorter messages that are 90- and 140-characters, 280-character messages likely do not contain sufficient information to overcome people's *pre-alert and warning event perceptions* of different hazards based on personal experience, and perceived risk and knowledge, which may or may not match the event they face. Hence, like 90- and 140-character messages, 280-character messages offer less to help effectively manage public protective action-taking than messages that are 1,380 characters.

Expanding message content. Should it become possible to expand the length of WEA messages in the future, it would be most important to expand the content areas communicating the hazard (what happened), guidance (what to do about it), and time until impact (when to do it). Expanding these three key message content areas is likely to result in the greatest impact on message outcomes and public warning response.

Effects of hyperlinks and apps. Including hyperlinks that display additional general information and using apps that provide more personalized information may be useful strategies for expanding the number of characters available for crafting WEA messages, and can potentially lead to improved public message outcomes and warning response.

In conclusion, findings indicate that while not a magic bullet, 280-character messages clearly are more effective at communicating imminent threats to at-risk publics than are the current 90-character WEA messages. In addition, the order of the content contained in an alert – whether it be 90 or 280 characters – remains a critical consideration along with message source. Adding apps and hyperlinks to WEA messages appears promising, but merits additional research. Adding maps, as tested here for messages that are 280 characters in length, was not promising, but merits additional research. In sum, the best course of action may be to optimize WEAs as best as possible along with other hazard information sources.

1. Background

This project sought to determine the optimized message content of Wireless Emergency Alerts (WEAs) distributed for extreme weather events. WEAs are 90-character messages distributed via mobile devices for "extreme weather, and other threatening emergencies in your area," AMBER alerts and Presidential Alerts during a national emergency.[3]

In practice, multiple WEA messages can be delivered across a weather event. Nevertheless, our research focus matches the general intention of the system: to view WEA messages as first alerts for imminent one-hour-to-impact threats. Consequently, we researched the first messages that would be distributed during an imminent threat weather event.

Previously, the team conducted eight experiments, seven focus groups, 50 think-out-loud interviews and a community event survey of a *"real world"* severe flood in Boulder, Colorado.[4] In this prior research, three different message lengths were investigated:

- 90-character messages *were the prime message length investigated since this is the message length delivered over today's WEA service. WEAs identify: (1) the type of hazard, (2) the time and location, (3) the severity of the hazard, (4) what action to take and (5) the message source.*
- 140-character messages *were also investigated because these are possible today using social media (e.g., Twitter), and they may be possible using the WEA service in the near-term future.*
- 1,380-character messages *were investigated because messages of this length are possible today in the description and instruction fields of Emergency Alert System (EAS) messages, and they may be possible using the WEA service in the longer-term future.*

1.1 Key Findings from START's Prior Research

Key findings from the team's prior research as summarized above include:

Message length efficacy. Longer messages (i.e., 1,380-character messages) appeared to produce optimized interpretation, personalization and milling outcomes, and would likely yield maximized public protective action-taking behavior. Shorter messages that are 90 and 140 characters appeared less effective at guiding people toward protective action-taking. However, 90-character WEAs were rapidly distributed and quickly reached a large percentage of at-risk populations, as found in the team's community event survey. What is likely the case is that people need to be provided with sufficiently detailed information about exactly what steps to take to protect themselves, and the number of characters needed to accomplish this likely varies across hazards.

Message content order. A different order for the content contained in 90-character WEA messages may improve public response outcomes. WEA messages currently use the following order: hazard, location, time, guidance and source. An alternative order had an advantage in improving the public outcomes tested: source, guidance, hazard, location and time. Although this alternative order only had a statistically weak advantage over the

[3] FEMA (n.d.). *Wireless Emergency Alerts*. Retrieved from https://www.fema.gov/wireless-emergency-alerts.

[4] Bean, H., Liu, B., Madden, S., Mileti, D., Sutton, J., & Wood, M. (2014). *Comprehensive testing of imminent threat messages for mobile devices*. Retrieved from http://www.firstresponder.gov/TechnologyDocuments/Comprehensive%20Testing%20of%20Imminent%20Threat%20Public%20Messages%20for%20Mobile%20Devices.pdf.

current WEA message content order, if put into practice, the effect of the revised order could be substantial considering how many more people in a population at risk might be inclined to take action in response to the revised order. The qualitative research provided support for this optimized message order for 140-character messages; however, it does not appear to transfer to 1,380-character messages for which the optimized order seems to be source, hazard, guidance, location and time.

Message source. Source in 90-character messages had a statistically significant effect on some public response outcomes including interpretation (understanding, believing and deciding) and personalization, and, hence, likelihood of protective action-taking. Quantitative and qualitative findings also suggested that local and recognizable sources might be the most productive sole source to name in a WEA message, but further research is needed to confirm these conclusions. Findings, however, did more conclusively suggest that if a sole source named in a WEA message was not recognizable to the public, then a vigorous public education and marketing campaign would be worthwhile. Quantitative findings also suggested that there may not be a single sole source that works for all WEA messages. The same conclusions were reached based on qualitative investigations of 140 and 1,380-character messages.

Inclusion of a hyperlink. Consideration should be given to including a hyperlink with additional information in wireless emergency alert and warning messages of any length. Doing so would be consistent with the long-standing historical observation that people who are warned engage in a search for additional information before taking a protective action, and this was reinforced in our focus group research. Findings from a community event survey also indicated that those who received a message with a hyperlink had a shorter delay (i.e., less milling) before beginning to check media compared to those who did not receive a message with a hyperlink. Delay time before avoiding flood areas was also shorter for those who received one or more messages containing a hyperlink (compared to those who did not).

Map inclusion. In the team's experiments, high information map inclusion (specifying the areas affected, areas not affected and the receiver's location) in 90-character messages had a statistically significant and positive effect on public response outcomes including interpretation and personalization, and, hence, could have a positive effect on protective action-taking. Inclusion of a low information map (specifying the areas affected and not affected, but not the receiver's location) had the opposite effect. Results from focus groups indicated that inclusion of a high information map improved most participants' understanding, belief and risk personalization across all message lengths. The community survey confirmed the relationship between receiving maps and increased personalization. These findings suggested that there would be a benefit from adding a high information map to a 90-character WEA message. Doing so could help the public interpret and personalize the worded message, which could move more people at risk to take protective action.

Generalizing across hazard types. Short 90- and 140-character messages were substantially less effective than 1,380-character messages at helping people overcome their pre-conceived perceptions about different hazards and likely would be less effective at guiding people to take protective actions appropriate to the risk they face in an actual event. The content elements of 1,380-character messages had standardized effects on outcomes regardless of hazard type (generalized across hazards). However, 90- and 140-character messages did not. Shorter messages do not appear to contain sufficient information to help people overcome their preconceptions about different hazards based on their personal experience, perceived risk and knowledge, which likely will not match the event they face.

1.2 New Research Questions

Given these prior findings, the research presented in this report examined the following questions:

1. Are 280 character WEA messages more effective than 90-character messages, and what is the best way to optimize character length should future WEA messages expand from 90 to 280 characters?
2. What is the best way to optimize maps, should future WEA messages have the capacity to include maps along with WEA messages, and what are the potential unintended consequences of including maps?
3. What is the potential added value (vs. unintended consequences) of including hyperlinks (i.e., web addresses) with additional general or static imminent threat information should future WEA messages have the capacity to do so?
4. What is the potential added value (vs. unintended consequences) of providing applications (apps) with additional personalized or dynamic imminent threat information, either along with a future WEA message or as a stand-alone product?
5. Do the findings generalize across hazards?

We answered these questions through focus groups and experiments (see Research Design Overview section, below, and Table 1, below).

Table 1. Research Questions by Research Phases

Primary Research Questions	Research Phase
1. How to best optimize character length (including message source) should future WEA messages expand from 90 to 280 characters?	Experiments 1, 2, 4, 5 and 7.
2. How to best optimize maps should future WEA messages have the capacity to include maps, along with any potential unintended consequences of including maps?	Exploratory focus groups; experiment 3; confirmatory focus groups.
3. The potential added value (vs. unintended consequences) of including hyperlinks (i.e., web addresses) with additional imminent threat information should future WEA messages have the capacity to do so?	Exploratory focus groups; experiment 8; confirmatory focus groups.

2. Research Design Overview

This multi-method project involved qualitative and quantitative research to determine how to optimize 280-character WEAs designed to alert the public to an imminent severe weather threat. First, two exploratory focus groups were conducted to test a tsunami warning. Next, the initial focus group findings were examined in a series of eight online experiments. This included testing flood and tornado hazards based on expert stakeholders' recommendations regarding hazard selection for this project, which allowed us to confirm whether findings are generalizable to multiple hazards.[5] Finally, two confirmatory focus groups, defined below, were conducted to review and expand on the experimental findings.

[5] Electronic communication on October 31, 2014 with Denis Gusty, DHS S&T First Responders Group, and Mike Gerber, NOAA. The team also consulted via telephone with Dr. Dennis Mileti, Professor Emeritus at the University of Colorado, Boulder along with Kate Long and Kevin Miller from the California Office of Emergency Management (October, 2014).

2.1 Exploratory Focus Groups

The initial focus groups were conducted to explore mostly *non-message* components of expanded 280-character WEA messages. Specifically, map features, hyperlinks and app features were examined, as described later in this report.

2.2 Experiments and Confirmatory Focus Groups

A series of experiments was conducted to build on the focus groups' findings and as a follow-up to the team's prior research on how to optimize 90-character mobile alert messages. The primary purpose of these experiments was to test whether previous findings about optimizing 90-character messages also applied to 280-character messages. Two new research questions also were included. Specific research questions and how they were addressed are detailed below.

Table 2. Phase IV experiments conducted and research questions asked

Experiment Number	Research Question
1	What is the optimal content order to include in 280-character WEA messages?
2	What is the optimal message source to include in 280-character WEA messages?
3	What effect do different map features have on 280-character WEA outcomes?
4	What is the effect of message length and map information on 280-character WEA outcomes?
5	What is the relative importance of 5 different message elements in 280-character WEA messages?
6	How do 280-character WEA message outcomes compare across different types of hazards?
7	What is the most effective way to "spend" the additional 190 characters when we expand WEA messages from 90 to 280 characters?
8	What effect does including hyperlinks to static and dynamic full text messages and maps have on 280-character WEA outcomes?

Finally, confirmatory focus groups were conducted based on experimental findings to assess participants' overall reactions to optimized 280-character messages.

3. Exploratory Focus Groups

Two focus groups were conducted to explore mostly *non-message* components of expanded 280-character WEA messages. Specifically, map features, hyperlinks and app features were examined, as described in this section.

3.1. Exploratory Focus Groups: Recruitment and Composition

Focus group participants were recruited from residents within and around Denver, Colorado via an advertisement placed on the Denver Craigslist Community page. The optimal size and duration for a focus group session is 6-12 participants and 1-2 hours. The exploratory focus groups totaled 12 participants, six in each session, which lasted 1.5 and 1.8 hours, respectively. The sessions occurred in the Communication Department conference room at the University of Colorado Denver and were moderated by the project's lead qualitative researcher. All participants were compensated with a $50 Visa gift card. The sessions were audio recorded and transcribed by a trained graduate student, but no personal identifiers were collected beyond basic demographic information.

3.2. Exploratory Focus Groups: Scenario, Questions, Messages and Maps

Focus group participants were first provided a tsunami scenario. Specifically, they were asked to imagine that they were on vacation in Southern California, shown a map of the area, and told that they were spending the afternoon at the beach in Corona Del Mar, just south of Newport Beach. The imagined time was 1:15 p.m. They were told to imagine that an alert appeared on their cellphone stating that a tsunami would soon strike the Orange County coastline. See Appendix A, Figures 1 and 2 for the focus groups' full interview guide and messages and maps tested. See below for one sample map.

Figure 1. Sample Map Tested in Exploratory Focus Groups

3.3. Exploratory Focus Groups: Findings

In this section, we report the focus groups' findings, which contributed to the experiments' design. Coding was conducted using NVivo 10, a software package that facilitates systematic thematic analysis. Coding focused on the study's primary research questions. Using a scissor-and-sort technique (Stewart & Shamdasani, 2015), similarities and differences in participants' stated responses to the messages were grouped and analyzed for recurring themes in order to answer the research questions.

Information needs. Participants were asked, "In a tsunami scenario, what information do you think you would need in order to be able to protect yourself?" Participant responses included:

- 1-click notification of contacts about one's safety.
- Closest evacuation transportation available.
- Current location of the tsunami.
- Definition and description of a tsunami.
- Distance inland needed to stay safe.
- Evacuation routes.
- Evacuation traffic flow.
- Information about how long the event will last.
- Information about what to do about kids in school.
- Instructions to "seek higher ground."
- Latitude, longitude and origin of tsunami.
- Location of communication center.
- Location of emergency services.
- Location of evacuation shelter(s).
- Location of roadblocks.
- Map with impact zones, one's location, safe zones, evacuation routes and emergency services providers.
- Safe areas.
- Seriousness of the tsunami alert.
- Severity of the tsunami and what will occur.
- Source of tsunami alert.
- Strength and characteristics of the tsunami.
- Time of alert and tsunami detection.
- Time of the tsunami impact.
- Weather patterns.

Participants were also asked, "From where, ideally, would you like to obtain that information (and why)?" In this scenario, participants wanted to receive the information via their phone (website, app or text), mass media channels (TV and radio) and lifeguards on the beach. Participant comments included:

> *So, like, an Amber Alert, for example, that would come up and be here and then also [in] lights, or on a billboard or something.*

> *I would think if there was a tagline in the alert that referenced you to a radio station. Because I think it's nice to have real information—real-time information—on your phone, but I think when you're listening to a radio station, you're just hearing it over and over and over, and when it's a blizzard alert, or whatever. And if there was a tagline in that, that referenced you to dial into—and if it didn't just say, "Tune into the radio to find out," but if it told you, you know, "Tune into this radio station," I think that lends volumes of credibility to it instantly.*

> *I think the more sources you can receive the information from, the more legitimate it seems.*

Current application (app) use. Participants were asked, "Do you currently use any disaster preparedness and/or severe weather apps and, if so, which ones and why? If not, why?" No participants currently used disaster preparedness apps. Many used weather apps for typical reasons (planning outdoor activities, etc.). Participant comments included:

I use a weather app that updates itself: forecast, temperatures.

I use the news apps, not a straight weather report.

I have the CDOT application, for road conditions.

Potential WEA apps. Participants were asked: "Would you be likely to open a mobile application with additional information and, if so, would you download this app or would you need the government to send it to you with a WEA message? If you would be unlikely to open a mobile application with additional information, why not?" In the first focus group, one participant explained that he would be "pissed" if the alerting authority required or requested an app download during an emergency situation. Other participants agreed with the sentiment. Most indicated that they would need to have downloaded the app prior to the event to be comfortable using it.

Additionally, some participants would want to check out the credibility and usefulness of the app before the event. Some would still seek additional and confirming information even if they had an app installed. A few participants stated that it would be helpful to have an app already installed on the phone at the time of purchase. Nobody in the second focus group indicated that they would download an app during an emergency. Participant comments included:

Yeah, I would want to know about the credibility. Either my friends have used the application, or have access to being able to read the ratings online. And under emergency circumstances, you may not have access to that information.

I'm thinking, 'This could be spam.'

I would like for it to already be on my phone.

As exemplified in the quotes above, for the second focus group, people explained they would prefer an app to be already installed at time of purchase. If a high-profile public awareness campaign about the app were conducted, combined with good word-of-mouth recommendation, participants would go to the app store to download it. Prior download would also hinge on one's perceived susceptibility to hazards. One participant suggested linking or combining it with a trusted app like weather.com.

When asked whether they would download an app (prior to the emergency) that provided the same information in the 1,380-character message plus the additional information, in dynamic form that was requested, five participants in the first focus group stated they would download it. The sole holdout stated he would expect such an app to already be installed at time of purchase.

In the second focus group, if the desired information were included, all participants indicated that they would prefer having the app instead of a link to the static 1,380-character message. However, these participants stated that they would need authoritative, trusted and repeated messaging before they would be motivated to download it.

Finally, participants provided the following additional feedback regarding apps:

- Address the texting and driving issue in some states that prohibit it.
- Enable configurable preferences in an app to accommodate information seekers and those who want to avoid information overload.
- Ensure the non-dominant groups have access and can use these technologies.
- Make sure the app does not count heavily against storage limits.

- Provide app tutorials and/or training.

Additional information via a hyperlink or app. Participants were asked: "In a URL (i.e., hyperlink) or app, what additional information would be 'critical' for you to have? What information would be 'nice' to have? What information would be 'unnecessary?'" Most, but not all, of the information listed above under information needs was deemed critical to have in a hyperlink or app. For example, some participants deemed "unnecessary" features to include the latitude and longitude of the hazard, information about how to be reunited with children, the location of the nearest airport, and a "1-click contacts notification" feature.

Participants were also asked, "Does it make a difference whether additional information is provided via a hyperlink versus an app? Why or why not?" In the first focus group, two people stated that they would prefer to have additional information available via an app, while four people preferred a hyperlink to a webpage. Perceived drawbacks to apps included, "too many bells and whistles, too many updates, too many things… inconsistent… problematic….;" "I just prefer a webpage;" and "Storage space… sometimes apps are unreliable." Perceived benefits of apps included potential dynamic content based on Global Positioning System (GPS) integration. A static webpage might not be updated quickly enough. Apps could be much faster in conveying updated information. However, in the tsunami scenario, four participants claimed they would click on a hyperlink for additional information, but all claimed that they would not click on a link to download an app.

Information sufficiency. Participants were asked, "How useful and sufficient is the 1,380-character message?" Some participants in the first focus group found the information sufficient. Others requested the following:

- Cities, towns, beaches and infrastructure impacted.
- Configurable preferences.
- Evacuation routes described.
- Locations of safe areas (specific distance or miles inland).
- More instruction on what to do to either protect yourself or help others.
- Safe floors in a high rise building.

A few participants thought the message was sufficient, but others thought it would cause panic (especially the "run" message in response to the seafloor being exposed). Some thought the organization of the message could be improved. In the second focus group, participants requested:

- A map indicating areas affected, safe zones, roads and evacuation routes, and other details.
- Clarification on how receivers will know that they are in the area at risk.
- Links or dropdowns to additional information and detail.
- Run-up zones indicated.
- "Tsunami Warning" needs to be at the top of the message.

Overall participant comments included:

> *I think it has all the information that we need—well, what information we asked for on the board.*
>
> *I do not know what a tsunami run-up zone is. Like, what the hell is that?*
>
> *What question came to mind for me is, what cities and towns are included in the warning. Also, on the infrastructure, which highways—roads—as well as beaches would be affected by this warning?*

Maps. Participants were asked: "Do you use maps on your smartphone and if so, why, and if not, why?" Every participant used maps on their smartphone, mostly for navigation and directions**.** In addition, almost every

participant stated that he or she would respond positively to a map on their smartphone during the tsunami scenario. Two participants in the second focus group were indifferent, believing that if textual information were sufficient, the map would be unnecessary.

Participants appreciated the speed and amount of information conveyed via a map: "A picture is worth a thousand words." Some participants speculated that people who "don't like being told what to do," are "not visual," or have difficulty readings maps would probably respond negatively. When asked what they would do next, following map receipt, participants in the first focus group said: "Google it;" "look to another human being;" "get in the car and go northeast!;" "look for corroboration from those around me;" or agreed with others. In the second focus group, some participants were concerned that a static map on a smartphone would cause confusion about whether the issuer really knew the receiver's location: "If it was not animated (the blue dot), I would not understand what is going on." Participant comments included:

> *I think the map would be pretty vital for me. Just maybe an expectation of what could the map look like—like, where's it going to hit—in addition to all the important information you need for evacuation.*
>
> *I would like to see it. Instead of just pushing for it to go somewhere else, I want it to be right then and there when I get all the information.*
>
> *That would make things much faster, so yes, I would like to see that there.*

Despite the enthusiasm for the maps, there was not a consensus on which of the maps displayed during the focus groups was most understandable. In addition, the maps did not always seem to produce the desired results. For example, participants further explained that if they were not near the indicated hazard area they would likely not take action. The closer one was to the hazard area, the more likely it was that he or she would take some type of action or more closely monitor the situation. Participants acknowledged that some people (but not themselves) would likely be tempted to observe the tsunami. Participant comments included:

> *There will always be people that do that.*
>
> *A lot of thrill seekers, like, they have those tornado chasers. Maybe some people would like to see that.*
>
> *I hope not!*

In terms of the map design, no participants found the grayscale maps more understandable or believable than the color maps. The lack of contrast in the grayscale maps created confusion for some participants, especially regarding the land or sea border and the hazard area. The colorful maps communicated more information more clearly, for the participants. One participant explained that if he received a black and white map on his smartphone during an emergency, he would be upset due to a perceived lack of technological sophistication. "If you have a color device, why would it not be in color?" said one. Also, some participants indicated that they did not understand the maps.

In terms of the boundary lines, almost all of the participants found the thick line more understandable than the thin line. However, a couple of people mentioned that the thin line showed that the area of danger extended inland in a way that the thick line did not. Some were concerned, however, that the thin red line too closely resembled the highway, so it was unclear what the line signified. When asked explicitly what the thick red line meant, four participants in the first focus group said "danger zone." However, one participant explained that it was too uniform and consistent for her to believe it.

In the second group, one participant explained that the thick red line was the strike zone, and others agreed, although one stated that the third map showed the hazard extended inland. However, this group also believed that the blue dot signified the point of impact, although some suspected it might be their location. One participant in the second focus group explained that even if he was pretty far away from the thick line, he would still be concerned due to the vagaries of technology.

For the location marker on the maps, four participants in the first focus group believed that the location marker referred to them, while one was sure it was the impact zone, and another was unsure whether it signified the impact zone or themselves. In the second focus group, all of the participants believed that the blue dot signified the tsunami impact point, but some also suspected it might signify them. One participant in the first group said that the color of the marker blended in too much with the ocean color. Another participant, however, thought that the blue shaded area around the dot signified an area of extreme danger and should be colored red.

When asked how we (the research team) could better indicate that the location marker signified one's location, participants in the first focus group said use a "standard graphic for a GPS," "you are here," a stick figure pedestrian, or words above the map that say the blue dot indicates "your location." The one participant who believed that the location marker signified his location explained that everyone knows that a pulsing blue dot meant one's location. When another participant noted that the dot was not pulsing, the participant was still "ok with it." In the second focus group, some said, "You are here" would explain the marker. Another person said, "Include a star." One did not understand what the blue shaded area around the dot signified. Most of these participants said that even if the dot was pulsing, they would not necessarily assume it was them.

When asked what we (the research team) could do to communicate that a receiver was in the area at risk, participants stated: "add a standard symbol or wording;" flashing "danger;" a radius of danger based on color; and traffic icons. When asked how their decision-making would change if the phrase "You are in the area at risk" was included, in the first focus group, two stated that it would not influence their actions. One person stated, "I'd leave." Another said, "I'd leave faster," and others agreed. The second focus group believed they were in the area at risk. A few said that the words would clarify, while others said they already believed they were at risk and did not need the words. Finally, the participants provided additional feedback regarding the tested maps, as follows:

- Add a map key.
- Add an explanation of the map's elements.
- Add instructions on how to stay out of the way of others who might make it if I am going to die.
- Add something textual saying, "You are in the danger area."
- An animated icon that better indicated that one should leave the area.
- A map better indicating safe areas.
- Include a sentence: "Impacted area shaded in X below."
- Indicate safe locations in green.
- Put an icon of where recipients should go (Others did not like being told what to do, however).
- Use shading more effectively to indicate higher risk and lower risk areas (Others speculated that could be misleading).
- Use red shading in terms of severity (or use terror code threat spectrum).
- Use a topographical map to show high ground.

Taken together, the exploratory focus groups' findings were used to help design the study's experiments, presented in the next section.

4. Experiments

Eight experiments were conducted to determine whether or not the findings from the team's prior research on 90-character WEA messages also apply to 280-character WEA messages (experiments 1-6). Two additional experiments were conducted to expand on prior research (experiments 7-8). The first of these sought to determine the most effective way to make use of the extra characters afforded by a 280-character WEA message (experiment 7). The second examined the potential utility of adding links, including general or static information, and apps, including personalized or dynamic information as a means of circumventing the 280-character limitation, and providing a full 1,380-character message (experiment 8). The experiments' methods and results are discussed below. An example questionnaire is in Appendix B. The questionnaire varied slightly for each experiment given each experiment's prime focus.

4.1. Experiments: Method

Eight experiments were conducted using a posttest only randomized design to replicate and expand on the team's prior research. Participants were randomly assigned to conditions; the experiments tested the relative effectiveness of different message features. For all experiments except for experiment number 7, messages described a tsunami event. For experiment number 7, messages were compared for three different hazards—tsunami, flood and tornado. Data were collected using SurveyMonkey software. See Figure 2, below for a sample message.

Figure 2. Sample Message Tested in Experiments

Message Text:

Emergency Alert
-California Office of Emergency Services. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Orange County coastal areas until 1:45 PM PST. Move now to high ground 50 feet above sea level and at least 6 blocks inland.

Sample. For the experiments ($N = 3{,}532$), eight volunteer samples were drawn from SurveyMonkey, which generated online survey audience panels of individuals recruited for experiment participation in exchange for

"points" in a no-cash, point system of rewards, including sweepstakes and merchandise.[6] Invitations were sent to help ensure sufficient cell sizes for gender and race and/or ethnicity. To be eligible to participate in this study, individuals had to be: (1) 18 years of age or older, (2) U.S. residents, (3) English speakers and (4) have a working cell phone. Descriptions of key sample characteristics for all experiments are presented in Appendix C, Table 1.

Measures. The online questionnaire included minor revisions to the questionnaire that was designed for and used in the team's prior research. The questionnaire incorporated standard questionnaire items used in prior research[7] when they existed and there was evidence that the items had performed well. In some cases, existing items were adapted to the particular context of the project. (See Appendix B for an example of the questionnaire used in the experiments.) The questionnaire took about 15 minutes to complete and contained mostly closed-ended questions, with a few open-ended items. It was pretested ($N = 19$) to identify any potential problems with programming, skip rules and question flow, and minor corrections were made.

Outcome Measures. The historical record of public response to alerts and warnings research guided selection of the items used in the team's prior research to indicate optimized outcomes. These were factors documented in prior research to intervene between receipt of an alert or warning message and initiating a protective action. Two general categories of outcomes were investigated: *perception* (Lindell & Perry, 2012; Mileti & Sorensen, 1990) and *milling* (Drabek, 1969; Griffin, Dunwoody, & Neuwirth, 1999; Mileti & Fitzpatrick, 1992).

Perception Outcomes. These are the perceptions that intervene between people receiving an alert or warning message and initiating a protective action. They are the perceptions people form to make personal sense—others call it sensemaking—out of a received alert or warning message. The perception outcome variables examined were:

- *Understanding*: attaching a personal meaning to the received warning message;
- *Believing*: determining if the risk, warning and message contents are accurate;
- *Personalizing*: coming to think that one is no longer safe and that the given warning is aimed at oneself; and
- *Deciding*: forming an idea about an appropriate course of action.

Milling Outcomes. Milling refers to people searching for additional and confirming information from other sources to help shape and reaffirm what one understands, believes, personalizes and decides to do or not do after receipt of a message (Mileti & Sorensen, 1990). Milling also includes sharing information with others. Based on the research record, optimized milling outcomes were cast as those with lower scores, as milling delays public protective action-taking.

Protective Action-Taking Outcomes. Protective action response behavior is the most important outcome factor of all, but it was not measured in the experiments as research suggests that behavioral protective action-taking intentions are not realistic estimates of protective action-taking in actual events with which people are not very

[6] The panels included a diverse group of individuals who have Internet access and have joined the Survey Monkey program to take surveys. Eligible panel members were invited by email to participate. Given that the tested messages were about hypothetical disasters occurring in California, participants were drawn largely from within the state so that the hazards would be familiar and the messages would be salient.

[7] See, for example, Gutteling, J. M. (1993). A field experiment in communicating a new risk: Effects of the source and a message containing explicit conclusions. *Basic and Applied Social Psychology, 14*(3), 295-316.; Kim, H. J., & Cameron, G. T. (2011). Emotions matter in crisis: The role of anger and sadness in the publics' response to crisis news framing and corporate crisis response. *Communication Research*, *38*(6), 826-855; Lindell, M. K., & Perry, R. W. (2012). The protective action decision model: Theoretical modifications and additional evidence. *Risk Analysis, 32*(4), 616-632.

familiar. Given that the perceptual outcomes measured are known to correlate with protective action-taking behavior (Kuligowski et al., 2012; Mileti & Sorensen, 1990), and because perceptions could be accurately measured in an experimental setting, the perception outcomes listed above were seen as better indicators of protective action-taking behavior than response behavioral intentions.

Scale Construction. For each experiment, subjects were randomized to condition as indicated in Tables 1-8, Appendix D. The text of the messages tested, based on randomization, are contained in Table 9, Appendix D; and the actual images that participants viewed, including maps, are included in Figures 1-8, Appendix D. The team's prior research used the same primary outcomes: understanding, believing, personalizing, deciding and milling. Scales were constructed to measure each of the outcome constructs. Exploratory and confirmatory factor analysis was conducted to guide scale construction (N = 3,532). Factor analysis in SPSS (Principal Axis Factoring and Varimax rotation) was used to assess whether the items reliably represented a single construct. Scree plot and eigenvalues were examined to determine the maximum number of possible factors for the potential items. Factor loadings were assessed and items that cross-loaded across factors were dropped. The coefficient alpha values ranged from .81 to .96. Skewness ranged from -1.64 to -0.41. Kurtosis ranged from -0.52 to 2.53. Descriptive statistics for the five factors are presented in Table 2 (see Appendix C). Constructs were operationalized and scales were constructed as follows.

Understanding. Understanding was measured by asking subjects to rate their level of agreement with seven statements using a six-point scale, where 1 represented "do not understand at all" and 6 represented "fully understand." The question stem was, "After reading this message, I understand," followed by seven statements. The seven statements rated were: "What happened," "The risks," "What to do to protect myself," "What location is affected," "Who the message is from," "When am I supposed to take action to protect myself," and "How long am I supposed to continue taking action to protect myself." All seven measures merged together to form the "understanding" factor.

Believing. Believing was measured by asking subjects, "After reading this message, do you believe that…" This question was followed by three items: "A tsunami is headed your way," "You should immediately take shelter," and "Sheltering will make you safer." Answers were rated using a six-point scale where 1 represented "do not believe" and 6 represented "believe." Experiment 8, which involved three different hazard types, used the same question structure and the following items: "Danger is headed your way," "You should immediately take action," and "Taking action will make you safer." All three measures merged together to form the "believing" factor.

Personalizing. Personalizing was measured by asking subjects, "How likely are each of the following statements? If I received this message on my cell phone, I would think that…" This question was followed by seven items: "I might become injured," "People I know might become injured," "People I don't know might become injured," "I might die," "People I know might die," "People I do not know might die," and "The message was meant for me." Answers were rated using a six-point scale where 1 represented "extremely unlikely" and 6 represented "extremely likely." All seven measures of personalizing merged into one factor.

Deciding. Deciding was measured by informing subjects to: "Use the scale below to show how much you agree or disagree with each statement. You may use any number on the scale." This was followed by four items: "The message will help me decide what to do," "It will be easy to decide what to do," "I will be able to decide what to do quickly," and "I can decide what to do with confidence." Answers were rated using a six-point scale where 1 represented "strongly disagree" and 6 represented "strongly agree." All four items merged into one factor.

Milling. Milling was measured by asking subjects the following question stem, "After receiving the warning message, how likely would you be to look for additional information about each of the following things before

beginning to take action? How likely would you be to look for additional information about:" followed by 14 items, including: "The size and speed of the tsunami; the physical consequences of the tsunami; what geographic area is likely to be affected by the tsunami; what you should do to protect yourself; how to take action to protect yourself; when you should begin taking action to protect yourself; how long you should continue taking action to protect yourself; how taking action can reduce your risk; what your family members are doing about the tsunami; what your friends are doing about the tsunami; what people whom you do not know are doing about the tsunami; the time the warning will end; and whether the warning message is 'real' or 'fake?'" Answers were rated using a six-point scale where 1 represented "very unlikely" and 6 represented "very likely." For experiment 6, which included three different types of hazards, "tsunami" was replaced with "hazard." The first eight of these measures of milling merged into one factor; other items were deleted to reduce redundancy.

Control Variables. Gender was measured with the question, "Are you male or female?" Race and/or ethnicity was measured by asking, "Which one of these racial/ethnic groups best describes you? Would you say: White; Hispanic or Latino; Black or African American; Asian; Native Hawaiian or other Pacific Islander; American Indian or Alaskan Native; or Other? If you identify with more than one, choose the group you identify with the most."

Procedure. Individuals who received the Survey Monkey invitation and wished to participate clicked on the embedded link and were taken to the consent form screen. Those agreeing to participate clicked the "continue" button; those who refused to participate clicked "refuse" or closed their browser. The questionnaire took approximately 15 minutes to complete. After completing the last item, participants were thanked for their participation and "debriefed" with a reminder that the messages viewed were hypothetical and not based on any real event.

Exploratory and confirmatory factor analysis was used to create composite outcome scores for multiple indicators of each outcome construct. Power calculations were performed using G*Power to determine necessary sample size. For all experiments except experiment 4, multiple linear regressions were conducted using the message received as the predictor and controlling on the selection criteria of gender, age, and race and/or ethnicity. Regression diagnostics were conducted to determine whether basic assumptions were met. For the independent variable, message received, k-1 dummy variables were created to represent the particular message viewed. Sex was coded as male and female; male served as the reference group (1 dummy variable). Race and/or ethnicity was recoded as Asian/Native Hawaiian/Pacific Islander, Latino/Hispanic, white and other; "white" served as the reference group (3 dummy variables). For experiment 4, analysis of variance was conducted to allow the testing of interaction effects for the ordinal message length variable, which had 4 categories. Relationships were classified as significant ($p \leq .05$), near significant ($.05 < p \leq .10$) and not significant ($.10 < p \leq 1.0$).[8]

4.2. Experiments: Findings

Experiment 1. Message content order. A WEA message similar to the ones auto-generated by the WEA service served as the control group. Power was calculated for the fixed model multiple linear regression (9 predictors total) testing the R^2 deviation from zero, to achieve a power of .85 for a small-medium effect size (.05) and alpha = .05, a sample size of $N = 358$ was needed (actual $N = 409$).

[8] Given the very slight changes in the test messages that were compared, a near significant result takes on meaning. This is precisely the situation in which one would consider a near significant result as important information (Warner, 2013, pp. 86-89).

Results from the multiple regression analysis examining the effects of different orders of message content are presented in Appendix C, Table 3. Individuals who viewed message order number five (source, hazard, location, time, guidance) had significantly higher levels of message understanding ($\beta = .159$, $p = .016$) as well as message belief ($\beta = .143$, $p = .030$) compared to those who viewed a message with content ordered as in the current WEA auto-generated message (hazard, location, time, guidance, source), while controlling on the subject selection factors of gender and race and/or ethnicity. Moreover, when compared to all other orders combined, order number five remained optimal, yielding significantly higher levels of understanding ($\beta = .112$, $p = .023$), belief ($\beta = .110$, $p = .026$) and deciding ($\beta = .103$, $p = .037$). This optimal order was: source, hazard, location, time and guidance.

Experiment 2. Message source. Local Office of Emergency Management served as the control group. Power was calculated for the fixed model multiple linear regression (8 predictors total) testing the R^2 deviation from zero; to achieve a power of .85 for a small-medium effect size (.05) and alpha = .05, a sample size of $N = 344$ was needed (actual $N = 398$).

Results from the multiple regression analysis examining the effects of different message sources are presented in Appendix C, Table 4. Individuals who viewed messages issued by NOAA had significantly higher levels of message understanding ($\beta = .162$, $p = .010$) as well as message deciding ($\beta = .146$, $p = .020$), and near significantly greater message belief ($\beta = .116$, $p = .065$) compared to those who viewed messages with the appropriate local source (i.e., the Orange County Office of Emergency Management), while controlling on the subject selection factors of gender and race and/or ethnicity. In addition, those who viewed a message with the National Weather Service as the source had significantly higher levels of deciding ($\beta. = .121$, $p = .050$). Thus, local sources may not always be the best sources. Instead, well-known federal sources can be just as, if not more, effective.

Experiment 3. Map elements. The order- and source-optimized message with no map served as the control group. Power was calculated for the fixed model multiple linear regression (11 predictors total) testing the R^2 deviation from zero; to achieve a power of .85 for a small-medium effect size (.05) and alpha = .05, a sample size of $N = 384$ was needed (actual $N = 484$).

Results from the multiple regression analysis examining the effects of different message map features are presented in Appendix C, Table 5. None of the message elements tested had a statistically significant effect on message outcomes.

Experiment 4. Message length efficacy. Two-way Analysis of Variance (ANOVA) tested for main and interaction effects for four levels of message length (90-, 140-, 280- and 1,380-character messages) and two levels of maps (present and absent). Power analysis showed that for the ANOVA fixed effects model with main effects and interactions (numerator degrees of freedom = 3, k groups = 8), to achieve a power of .85 for a small-medium effect size (.05) and alpha = .05, a sample size of $N = 312$ was needed (actual $N = 415$).

There was a significant effect of message length on message understanding [$F(3,407) = 6.74$, MSE[9] $= 7.56$, $p < .001$] and on deciding [$F(3,407) = 4.56$, $MSE = 6.54$, $p = .004$]. There also was a significant interaction between message length and adding a map for understanding [$F(3,407) = 3.19$, $MSE = 3.58$, $p = .024$] and also for milling [$F(3,407) = 2.95$, $MSE = 5.76$, $p = .033$]. See Appendix C, Tables 6a and 6b.

Post hoc analyses using Tukey's Honest Significant Difference (HSD) test indicated that adding a map yielded higher levels of understanding for both 90-character ($M = 4.44$) and 140-character ($M = 4.63$) messages compared to 90-character ($M = 4.00$) and 140-character ($M = 4.47$) messages without a map; however, the

[9] MSE stands for Mean Squared Error.

opposite was true for longer messages. Adding a map yielded lower levels of understanding for both 280-character ($M = 4.55$) and 1,380-character ($M = 4.72$) messages compared to 280-character ($M = 4.89$) and 1,380-character ($M = 5.04$) messages without a map. In addition, for short 90-character messages ($M = 4.50$), adding a map led to an increase in milling compared to 90-character messages without a map ($M = 3.76$). In comparison, adding a map to 140-character ($M = 4.22$), 280-character ($M = 4.09$), and 1,380-character ($M = 3.96$) messages led to lower levels of milling (i.e., reduced response delay) compared to 140-character ($M = 4.42$), 280-character ($M = 4.32$), and 1,380-character ($M = 4.28$) messages without a map.

Finally, level of deciding was higher for individuals who viewed a 280-character message ($M = 4.32$) compared to those who viewed a 90-character message ($M = 4.94$). Charts showing each outcome by message length and map status are included in Appendix C, Figures 1-5. Overall, the results indicate that the effect of maps varies by message length.

Experiment 5. Relative importance of content elements. Messages that were missing one of the key message elements were compared; the complete 280-character message served as the control. Power was calculated for the fixed model multiple linear regression (9 predictors total) testing the R^2 deviation from zero; to achieve a power of .85 for a small-medium effect size (.05) and alpha = .05, a sample size of $N = 358$ was needed (actual $N = 439$).

Results from the multiple regression analysis examining the effects of different omitted message elements are presented in Appendix C, Table 7. Individuals who viewed a message that was missing information about guidance had significantly lower levels of message understanding ($\beta = -.172$, $p = .003$) and deciding ($\beta = -.220$, $p < .001$); those who viewed a message that was missing information about time until impact had significantly lower levels of message understanding ($\beta = -.151$, $p = .011$), belief ($\beta = -.123$, $p = .040$) and deciding ($\beta = .127$, $p = .031$); and those who viewed a message that was missing information about message source had significantly lower levels of personalization ($\beta = -.145$, $p = .011$) and deciding ($\beta = -.141$, $p = .012$), compared to those who viewed complete 280-character optimized messages, while controlling on the subject selection factors of gender and race and/or ethnicity.

Experiment 6. Generalizing across hazard types. Outcomes were compared for three different hazard types: tsunamis, floods and tornadoes. The tsunami message served as the control. Power was calculated for the fixed model multiple linear regression (6 predictors total) testing the R^2 deviation from zero; to achieve a power of .85 for a small-medium effect size (.05) and alpha = .05, a sample size of $N = 312$ was needed (actual $N = 373$).

Results from the multiple regression analysis examining the effects of different hazard types on message outcomes are presented in Appendix C, Table 8. Individuals who viewed a 280-character message that was about a tornado event had significantly lower levels of message belief ($\beta = -.183$, $p = .003$), personalization ($\beta = -.164$, $p = .007$) and deciding ($\beta = -.131$, $p = .033$); those who viewed a message about a flash flood event had significantly lower levels of message belief ($\beta = -.176$, $p = .004$) and personalization ($\beta = -.205$, $p = .001$), compared to those who viewed a 280-character message about a tsunami, while controlling on the subject selection factors of gender and race and/or ethnicity. In sum, the findings do not generalize across hazards for 280-character messages.

Experiment 7: Expanding the message content. Messages that included different expanded content elements were compared; the order- and source-optimized 280-character message was used as a control group. Power was calculated for the fixed model multiple linear regression (9 predictors total) testing the R^2 deviation from zero; to achieve a power of .85 for a small-medium effect size (.05) and alpha = .05, a sample size of $N = 358$ was needed (actual $N = 434$).

Results from the multiple regression analysis examining the effects of expanding different message content are

presented in Appendix C, Table 9. Individuals who viewed the optimized 280-character WEA message that was expanded to include additional information about the hazard had significantly higher levels of message understanding ($\beta = .182$, $p = .002$) and deciding ($\beta = .209$, $p <. 001$); those who viewed a message with expanded information about guidance had significantly higher levels of message belief ($\beta = .126$, $p = .032$); and those who viewed a message with expanded information about the hazard, guidance and time to impact had significantly higher levels of message understanding ($\beta = .141$, $p = .018$), personalization ($\beta = .119$, $p = .050$), deciding ($\beta = .219$, $p < .0041$) and near significantly lower levels of milling ($\beta = -.105$, $p = .084$), compared to those who viewed the 280-character optimized WEA message, while controlling on the subject selection factors of gender and race and/or ethnicity. Thus, it is most important to expand the content areas communicating the hazard (what happened), guidance (what to do about it) and time to impact (when to do it).

Experiment 8: Effect of hyperlinks and apps. Messages that contained a hyperlink with expanded general or static information and an application ("app") with expanded or dynamic personalized information were compared to an optimized 280-character message, both with and without maps. Power was calculated for the fixed model multiple linear regression (9 predictors total) testing the R^2 deviation from zero; to achieve a power of .85 for a small-medium effect size (.05) and alpha = .05, a sample size of $N = 358$ was needed (actual $N = 580$).

Results from the multiple regression analysis examining the effects of adding a hyperlink displaying general information and an app displaying personalized information are presented in Appendix C, Table 10. Level of understanding was significantly higher for individuals who viewed the optimized 280-character WEA message that also included an app containing additional personalized information ($\beta = .130$, $p = .010$), and for those viewing a message that included an app containing additional personalized information plus a map ($\beta = .119$, $p = .019$), compared to those who viewed the 280-character optimized WEA message, while controlling on the subject selection factors of gender and race and/or ethnicity.

Level of understanding also was significantly higher for individuals who viewed the optimized 280-character WEA message that also included a link to additional general information ($\beta = .108$, $p = .037$), and approached significance for those who saw a message containing a link to additional general information plus a map ($\beta = .087$, $p = .084$). Therefore, including hyperlinks and using apps may be useful strategies for expanding the number of characters available for crafting WEA messages.

5. Confirmatory Focus Groups

Four focus groups were conducted in Denver, Colorado for the purpose of exploring people's interpretations of optimized 280-character messages for tsunami, tornado and flood hazards. Based on the quantitative experiment results presented in this report, these messages were written in a way to optimize the outcome variables of understanding, belief and personalization. See Figure 3, on the following page, for messages tested in the confirmatory focus groups; the full text of tested messages are displayed in Appendix E.

Figure 3. Messages Tested in Confirmatory Focus Groups

Tsunami Message

Tsunami Message with Map

Tornado Message

-+

Flood Message

5.2. Confirmatory Focus Groups: Scenario, Questions, Messages and Maps

Members of the focus groups were asked to discuss the sufficiency and usefulness of the optimized messages, as well as the specific language used to construct the messages. The messages were mock WEA messages appearing over an iPhone lock screen and were printed (in color) on a piece of paper given to each participant.

The mock messages were roughly the same size they would be on an actual iPhone; these are presented in Appendix E.

The messages were presented in the following order to participants: (a) tsunami, (b) tornado and (c) flood. Participants were also asked about whether or not they could and/or would follow the protective action guidance presented in the messages. Focus group members discussed their impressions of applications (apps) and hyperlinks related to WEA messaging, as well as the desirability of a map for the tsunami hazard.[10] Public education about the WEA system was also discussed. Focus group participants were first provided a tsunami scenario. Specifically, they were asked to imagine that they were on vacation in Southern California and told that they were spending the afternoon at the beach in Corona Del Mar, just south of Newport Beach. The imagined time was 12:00 p.m. They were told to imagine that an alert appeared on their cellphone stating that a tsunami would soon strike the Orange County coastline. After the text-only message, the groups were presented with the same message that included a map. Questions about the map then followed. Subsequently, the participants were asked to imagine that they were at their home in or near Denver when they received, first, a tornado message, and, second, a flood message. Each message was discussed in turn. See Appendix E for the focus groups' interview guides.

5.3. Confirmatory Focus Groups: Findings Summary

Following the same data analysis procedures for the exploratory focus groups, analysis of the confirmatory focus groups yielded the following insights.

Message sufficiency. Each group discussion began with commentary regarding the sufficiency of the information contained in the 280-character tsunami message. Message sufficiency was also assessed for the tornado and flood messages. Sufficiency was evaluated in terms of participants' perceptions concerning whether or not the information contained in the message was sufficient to allow them to protect themselves. The participants generally deemed the 280-character tsunami message sufficient, with lower levels of sufficiency reported for the tornado and flood messages.

For the tsunami message, participants noted that the message provided the time of the hazard's arrival and instructions for how to evacuate. It provided information about the hazard through the estimated height of the wave, which could help participants determine where to evacuate. NOAA was deemed a credible source; however, many participants initially did not know the acronym's meaning, but they assumed it referred to an authoritative source. As one participant explained, "I just figured it [the acronym] was from the agency that discovered the tsunami, but I didn't think to decipher that acronym, I guess." Another stated: "I thought it was just a person or company handling the alert."

Participants' explanations about why they believed the tsunami message was sufficient included:

> *So, I think it gives you pretty much the gist of everything—what's happening, what exactly it is, what's going to happen, the time, and how to evacuate, basically.*
>
> *I thought that it was nice that they offered a couple of different options to get yourself out of the way of danger.*
>
> *...it tells me the wave is coming at 1:00 pm and it tells me exactly what to do. It's pretty much all you need, I think.*

[10] Tornado and flood maps were not tested in the experiments; therefore, no optimized maps or map-related data were available for presentation to or comparison with the focus groups.

Participants who deemed the tsunami message insufficient explained that the message lacked specific locations for the areas at risk. However, multiple participants noted that such specificity could be misleading, thus offering a false sense of security. A participant suggested that a date and time be included in the message to confirm its timeliness. Another noted that there were no evacuation routes or safe locations specified. Another stated that there might be too much information in the message to make sense of conditions under imminent threat. As examples of these themes, participants' comments included the following:

> *It says 'move now to high ground 50 feet above sea level,' but it doesn't give me information about where that might be. It just says get there by 1:00 pm. It's 12:30, so I have half an hour to figure that out.*
>
> *I feel like it needs to give us more information about where a safe place would be other than simply the sea level height.*
>
> *This could be potentially confusing. There might be time that you're going to need to get away to safety that you're [instead] going spend trying to figure this [message] out.*
>
> *Give me a whole message that tells me exactly what I need to know and explains it clearly, and make it about twice as long in clear language, or just make a simple message. There's almost too much information here to make it be efficient and effective…*
>
> *So, I want to see a spatial aspect letting me know whether I'm in the highest danger zone. Because it's so vague, I don't know if it's really applicable to me.*

For the tornado and flood messages, there were fewer comments regarding what specific elements led to their sufficiency, although one participant stated:

> *It tells you what's going on [a tornado], but it may develop what to do. Avoid windows. I think that's pretty sufficient for just an alert, and a heads up for what's happening. It's a good message.*

Prior hazard experience also appeared to play a role in assessment of sufficiency for some participants. As two participants stated:

> *I've had to evacuate for tornado warnings before. I've also lived in Colorado my whole life, so that contextual experience that I have, may contribute to the sufficiency of this.*
>
> *Flash flooding is super dangerous, I know. So, as soon as I read 'flash flood warning,' I knew this is serious, imminent danger, and I need to get the heck out of there. So, even that first line was enough for me.*

A higher proportion of participants deemed the tornado and flood messages insufficient in comparison to the tsunami message, leading to immediate discussion of those insufficiencies. Those who expressed concern about the sufficiency of the information in the tornado message cited perceived ambiguity about the location of the hazard, time to impact (if impact at all), adequacy of the protective action guidance, and what to do if one is in a vehicle. Comments reflecting these themes included:

> *I don't know the exact location of where the tornado may be or may be coming to, as opposed to the tsunami warning with the beaches. So, that's why I felt confused.*
>
> *I just think the wordings of the shelters are a little vague.*
>
> *I don't like the wording 'a funnel cloud was reported in this area.' I don't know what area that is.*

For the flood message, those who expressed concern about the sufficiency of the information cited ambiguity about the area at risk, what constituted higher ground and what to do if higher ground was unavailable. Representative comments included:

> *It's not obvious [what] higher ground would be. What? The roof of your house? I think that's my only question; just my level of understanding of what higher ground is.*
>
> *It's insufficient for me because I don't really know a lot about flash flood. Am I safe from a flash flood if I'm in my house? I don't know and this doesn't tell me. I mean, higher ground, do I stay inside or go outside and go up a hill? I really don't know.*
>
> *For me, it's not sufficient information because I don't know what to do if I'm at home. Like, I live in a flat area and I don't know what's higher.*

Sufficiency, milling and threat denial. Consistent with the team's prior research findings and historical studies (Bean, Wood, Mileti, Liu, Sutton, & Madden, 2014; Drabek, 1999; Mileti & Sorensen, 1990), several of those who deemed the messages insufficient stated that they would search for additional and confirming information before taking action, thereby delaying protective response. Others stated that they would likely ignore the message. Among the comments reflecting milling intentions or threat denial for the tsunami, tornado and flood messages were the following:

> *I would have to wait and look it up myself on a website and see if it was a serious warning.*
>
> *I would seek more information…Probably just look it up on my phone on Google.*
>
> *From what I know, it doesn't seem like it's that big of a deal, so it doesn't seem like the message is urgent to me.*
>
> *I would walk outside and look around me [for a tornado] if it didn't seem that bad. And I've gotten this type of message before, and I didn't really hesitate.*
>
> *I would probably turn on the TV or radio to find another source that could be reporting on it [the tornado]. I could contact family, girlfriend, some other people in the area to see where they are, what to do being that they live here and are from here.*
>
> *[For the flood message, I would] go outside, see if the water is actually coming. There's no…it says it could happen at any time, so it could be at that moment. So, I'm going to see if there's actually an immediate hazard.*
>
> *Realistically, I probably would [look for additional information] because that's how I am. I'd find out where it [the tsunami] is.*

When asked to speculate about what words could be added, removed or modified to transform an insufficient message into a sufficient one, participants' focused on additional information and the use of more urgent language. Comments included:

> *Provide a link to a website and give a breakdown for people who don't know [about tornados]. You have to assume that people who have no experience with tornados would be reading it, so give the types of warnings like 'warning advisory' or 'emergency' and just general safety evacuation procedures and where to evacuate if you were in that place.*
>
> *So, something that would make me take action is just saying 'take action now,' then I probably*

would.

Maybe something like 'alert' or 'critical' or something. If it's 12:30 and it's going to happen at 1:00, I need to move now. Not like, 'oh, I have a few minutes, it's just a warning, it's not coming right away.' So, maybe something a little more immediate in the beginning.

Despite these comments, in comparison to the team's prior research, 280-character messages appear superior to 90- and 140-character messages in terms of participants' stated understanding, belief, personalization and intention to comply with protective-action guidance. Also in comparison to the team's prior research, where several focus group participants deemed 1,380-character messages too long, few participants directly described the 280-character messages as too long, although one stated of the tornado message, "So, when it comes to emergency alerts on my phone, I think less is more: The less information you have on there, the more likely I'm going to read the message, the more likely I'm going to follow the message." The five other participants in this group agreed with this participant's statement. However, the nature of the tornado message, and its uncertainty in comparison to the tsunami message, may have contributed to this outcome. As one participant explained:

This is not a tornado happening right now, take cover. This is 'oh, there's a funnel cloud and a tornado may develop.' I'm going to go look out the window and be like 'is there a funnel cloud? No? That's cool' and go back to doing my homework. It's too much [information] … it makes it less of an emergency.

Nevertheless, one participant remarked of the tsunami message:

…the more information you give, the more confusing it gets. The more likely people are to miss the important information they put in there. So, I think if it were possible for them to put a link to set up this page on their website that has a map and severity information and all that kind of stuff you could possibly want [it would be good].

In addition, comments indicated that hazard familiarity played a role in how much information participants deemed sufficient and optimal. However, there was no clear-cut association: both those with little or substantial hazard experience voiced preference for both longer or shorter messages. The optimal order of message content might also be different based on the receiver's familiarity with a given hazard. Those who were familiar with the tornado and flood hazards, for example, appeared to be off-put by the descriptions of the hazard's consequences contained at the beginning of the messages. These participants instead wanted clear and immediate descriptions of the severity and protective-action guidance. As one stated:

I know what these hazards are [tornado and flood]. For you to start out telling me what the risk is, is like 'Okay, I get it,' and I might not read any further than that because I already know that. If you're just telling me there's a risk, if you're telling me 'Well, in a flash flood blah blah blah can happen,' I know that. You don't tell me I have to act now. And I think the difference—I don't know if this has been accounted for in the research data—but there's a difference…when I'm sitting in this room thinking about getting this message, I'm thinking about it differently than if I am actually in an emergency.

This participant's comment underscores that participant *preferences* for certain message lengths, degrees of certainty and content order should not be conflated with actual improvements in outcomes including understanding, belief and personalization.

Additional information sought for self-protection. Participants offered a variety of opinions regarding the types of additional information they would like to see in a WEA. For one participant, the tsunami message's location information, "in this area," was insufficient and potentially misleading. This participant was concerned

about adequate warning "if the phone's location was incorrect for some reason, or if it was late, or something like that." Another asked, "How do they [officials] know that you're there [in this area]? … What if you have your location services turned off?"

Participants sought additional information regarding precise evacuation instructions and locations. One participant noted that some elderly people might not trust technology; therefore, specifying the date, time and location in the message itself would be very useful. One participant desired a phone number for more information. Another suggested adding more specificity about the coastal areas affected, e.g., Huntington Beach, Venice Beach, etc. Consistent with the team's prior research,[11] the words "watch" and "warning" created uncertainty for some participants. One stated, "So, I don't know if for a tsunami it's just a 'warning,' but if you have a tsunami 'watch' and a tsunami 'warning,' I think it needs to be clarified which is which." A few participants also desired information about the category level of the tsunami. Participants explained that they would, ideally, like to receive this additional information via their mobile device, but opinions differed on how, exactly, that should be obtained (e.g., additional WEAs, SMS or Internet). Other preferred channels for information acquisition included megaphones, sirens, loudspeakers, television and radio.

Protective action guidance. Following discussion of the sufficiency of the information contained in the message, participants were asked whether or not they *could* and/or *would* follow the protective action guidance provided in the message. Participants universally stated that they could and would follow the protective action guidance provided in the tsunami message, with lower levels of ability and intention to comply with the tornado and flood message guidance.

Participants stated that the tsunami message provided easy-to-follow guidance and multiple ways to follow it. A few noted that they would likely be observing others taking action, which would reinforce the need to do so. Among the comments reflecting participants' ability and willingness to follow the tsunami message guidance were the following:

> *I think it was helpful that they said six blocks and 50 feet.*
>
> *Honestly, I would be afraid so I would probably try to do all of these things. I would go as far inland as could and try to get to high ground because I would be afraid of not knowing what to do in the situation.*
>
> *I've never experienced anything like this, so I think my first reaction would be to do whatever I could to avoid it.*
>
> *I think it provides us information, detailed information, in order to act quickly given that it's a thirty-minute window and that it's very general also.*
>
> *My rationale for following the guidance is because I'm assuming if I'm getting this notification, then I'm in danger. And I would much rather, if I'm at a hotel by the beach, it doesn't seem it would be that hard to move away. I'd rather be safe about a tsunami.*

A few participants noted that the novelty of the tsunami hazard might compel them and others to only partially heed the protective action guidance and instead attempt to observe the hazard. One participant stated, "I would probably seek higher ground, but I don't think I would go too far inland because I would want to watch it [the tsunami] to be honest, because I'm curious." Even participants who deemed the message insufficient stated that

[11] See Bean, H., Wood, M., Mileti, D., Liu, B. F., Sutton, J., & Madden, S. (2014). Final Report. Comprehensive Testing of Imminent Threat Public Messages for Mobile Devices. Report to the Homeland Security Advanced Research Projects Agency, Science and Technology Directorate, U.S. Department of Homeland Security.

they would nevertheless heed its guidance. One said, "Yes, I would [follow the guidance] because just from what I've learned from past tsunamis, the fatalities are from people who have ignored warning signs. So, I wouldn't want to be one of those statistics. So, I would follow the warning signs even though I feel like they could be more sufficient." Another agreed, "It's better to be safe than sorry, and I would probably confirm the warning as I was taking action." Only one participant explained that she might not follow the tsunami message guidance; specifically this participant stated that she would head in a direction away from others evacuating in order to avoid a glut of people.

In terms of the tornado and flood messages, those who claimed that they could not follow the tornado guidance stated that they were unfamiliar with the hazard and did not know how to adequately protect themselves. For the flood message, one participant speculated about evacuation conditions. Participant comments about these situations included:

> *I grew up in California and we didn't have those [tornados]. For the interior room on the lower level, I don't have a basement. I guess I could avoid windows, but other than that, I would probably just stay at home and not go outside. I don't know.*
>
> *…there might be a panic situation [during a flood] so being able to do it [evacuate] might not be as possible if you have a panic. The roads might be crowded.*
>
> *[I could not follow the tornado guidance] Because it doesn't tell me the direction of the storm, and I might just be running towards it without realizing it and being like 'oh well too bad now.'*

Those who claimed that they would not follow the tornado guidance cited the hazard's unpredictability, prior false alarms that they have personally experienced, and that only a "funnel cloud" had been reported, rather than a tornado "on the ground." Hazard familiarity appeared particularly salient. As three participants explained:

> *If I lived somewhere other than Colorado and didn't see these [alerts], then maybe I would take more warning. But this would encourage me to look outside and get a better feel of what's going on, but I would not be incredibly worried if I got that.*
>
> *So, I know that I should move, but I remember there was a tornado warning a while back in my building, and that's exactly what I did. I was like, well I know where I should go but I wasn't there the whole time.*
>
> *I'd come back to my apartment and look around and see it was super dark out or whatever.*
>
> *It could be it was reported and gone, or it was reported and now it's on the ground. You don't know.*

The tornado message also was written in an uncertain tone, as one participant observed:

> *I think, going back to the tsunami alert, if there were words in there like 'may develop' [or] 'has been spotted' that it would have added those elements of doubt that I'm getting in this one. It's the element of doubt that is leading me to not take action.*

It is worth noting that those who stated that they would not follow the tornado guidance were both people who claimed a lack of hazard familiarity and those who claimed a great deal of hazard familiarity. It may be the case that the nature of the tsunami hazard, and the wording of the message, was clearer and more certain to participants in comparison to the tornado and flood messages. As one participant explained:

> *And of course, I know what a tsunami is. Even if I didn't, it says 40-foot waves, so it seemed like an easy one to me [to evacuate the area].*

Those who claimed that they could not or would not follow the flood guidance cited that they had no previous experience with the hazard and were unsure what to do, or, conversely, had previous experiences with floods and/or would prefer to confirm the hazard with their own eyes before taking action. For example, comments included:

> *I don't know if I stay home or if I leave.*
>
> *My main concern here is that it says 'move to higher ground,' but should I leave my house to go to higher ground? I feel like I wish it would say 'if you are inside, move to the highest level' or 'if you are unable to get to the highest ground in your area, get up or stay inside or what.' I would not know what to do at all.*

Hyperlinks and apps. The groups were asked about the desirability and intentions to click on or use hyperlinks and download or use apps for the tsunami message. The groups differed in their responses, with some groups generally preferring hyperlinks and others preferring apps. In general, more people reported a willingness to click on a hyperlinks, rather than use an app.

The overwhelming reason given for the desirability of a hyperlink was the possibility of additional information. As one participant stated, "I'm always trying to find out more information. The more I have, the better." Reasons given for the undesirability of a hyperlink included the possibility of the message being a hoax, scam or virus. Reasons given for the desirability of an app included the presumption of more tailored and comprehensive information. One stated, "Some people are more likely to trust a website, but I think something like a pre-loaded app will be easier on Internet resources, so people with poor Internet connections can get more data, and it'll be less effort for people in general." Other comments included:

> *It's better than a website, to work on a phone. Unless it's a website specifically formatted for cell phones, but sometimes websites are such pains. But an app is clear and it's much easier to navigate.*
>
> *I feel like I trust apps, especially if it's coming from an emergency alert and they have attached an app, so I'd be like 'that's legit.' Whereas if I was to get a 'click this link to see more,' I feel like when I'm on the Internet I see that all the time and get viruses.*

The reasons given for the relative undesirability of an app in comparison to a hyperlink included suspicions about the security of the app, its reliability, complexity and probable time-consuming installation. One participant explained, "It [an app] just seems too complicated. I think the hyperlink is just easy, and I'm not much of an app-person on my phone, so it's just whatever's the simplest. Opening up the app and figuring out the app is too much. I don't want to go through all of that." Other comments regarding the undesirability of an app (particularly one that needed to be downloaded during an emergency) included the following:

> *Having to download something in that moment shifts your action from evacuating to downloading to get more information, and you're swept away in the waves.*
>
> *For me, if somebody asks me to download an app, it feels 'spam-y.'*

Even those who expressed interest in apps generally stated that they would need to download it well ahead of any event, rather than during an emergency. Participants' comments reflecting this theme included:

> *The qualification there would be that this warning wants me to do something right away. I'm not going to spend the time to install something, especially because I know, one, that sometimes stuff you download doesn't always work and, two, I'm automatically suspect of things people try to push to my phone. So, it's a qualified yes for me.*

> *I would open it only if it was already on my phone. So, for example, if it linked me to the map or iMaps, I would click on it. But if it's not already on my phone, I'm not going to download it.*

Other types of information that a hyperlink or app ought to contain, according to participants, included the time that the tsunami is expected to not be a threat, real-time tsunami tracking, a basic map, or an interactive map showing locations of danger and safety. Others mentioned the scale of the hazard, the precautions, the evacuation procedures, evacuation routes and traffic flow information.

Map desirability and use. Following discussion of hyperlinks and apps for the tsunami message, the groups were presented the same mock message, but one containing a map of a portion of the Southern California coastline, the hazard area, location markers and other elements identified. The groups generally preferred the message that contained the map. However, most participants did not deem the map necessary for message sufficiency. Participants who desired a map did so primarily due to the perceived value of visual reinforcement. Related comments included:

> *I just like visual images, so that's why I like the map. It kind of puts it into a visual perspective where I am location-wise, and I guess where the tsunami is going to hit location-wise as well.*
>
> *It solidifies a lot of the vague information from the first message. So it provides a physical area and your location. So that resolves the issue of maybe your location is an error or people not knowing where 50 feet above sea level is, etc.*
>
> *For me, the map is very important. It assures me that I'm actually supposed to receive this message. Anyway, I think I would take action, but this is reassuring. I would be certain that that's for me [the message].*
>
> *For me, what was missing in the first message was a visual, attention-getting, here's where you are, here's where it's safe. I feel like it's a really critical element that was missing before, and it's incredibly helpful in this message.*
>
> *I really liked the red shading just to make sure you're out of the [danger] zone.*

Some noted that the text included with the map usefully reinforced its meaning, although its placement and formatting might have been improved for some:

> *I really think that the 'you are in an area of risk' is important.*

Those who preferred not to have a map or had no preference voiced concerns about the perceived quality of the map, missing elements or its potential to distract from the message. Comments along these lines included:

> *So, I definitely agree with all the points that people are advocating for the map had. The only problem I had is that when I got the message, I looked at the map and not the warning. So, I didn't think 'Oh, I should probably get out of here.' I just thought about what is this map.*
>
> *Although it shows the area that's at risk, it doesn't show where to go.*
>
> *I think it distracts from the message and it doesn't offer any pertinent information.*

While there was a strong preference for map inclusion, when the issue turned to the *necessity* of including a map, there was more variability. Comments from those who believed the map was necessary included:

> *I just think it's necessary because like even for people that maybe can't see too well, like if they don't have their glasses with them, like my dad who probably can't read this. But if he were to see a picture and see that we need to go somewhere else because we're in danger, I think that would help him out a lot.*
>
> *It allows you to jump into action much faster because it places you—it just gives you the information in a good, concise and fast way.*

Those who were unsure about the necessity of a map expressed sentiments similar to these:

> *It's kind of hard to say because if you were to say were you better to receive a message with this or a message without the map, I would say yes this is better. But receiving a message without a map would be better than receiving no message at all. So I guess it kind of depends on how you define necessary. I think it's definitely better with the map but without the map is better than nothing at all.*
>
> *I think the message gives all the information it needs to give. But I like the map or additional information.*

Some of those who deemed the map unnecessary qualified their response:

> *I don't think it's [a map] absolutely critical, but I think it provides very important information, so I wouldn't say it's completely unnecessary.*
>
> *Just thinking we already went through this scenario when it was just the text and that was good enough for us to realize we need to do something. So, the map's not necessary. I still prefer it to the one without the map, but I think either would be sufficient to tell me something's going on.*

Participants generally found the map to be understandable; however, some voiced confusion about specific elements including the scale, areas of risk and safety outside the depicted area, the nature of the red line, and inability to use the functionality associated with Google Maps and location services. A few participants speculated that GPS tracking could make people suspicious or angry about receiving a WEA. For example, participants said:

> *I think that speaks to what [another participant] was saying earlier about location services and the concern with people knowing where you are and what you're doing, and the security purpose of this almost infringing on people's privacy right. I think that probably plays into it.*
>
> *I would want to know that this was coming from someone I absolutely trusted, particularly because now you're putting a map on my phone and telling me where to go. Right, if I'm already paranoid, that's just going to make things worse.*

When asked specifically about whether their interpretation and response would change based on their proximity to the edge of the hazard area indicated on the map, participants voiced intentions to either take the same protective actions or modify those actions. Those who would still heed the protective action guidance offered comments including:

> *I'm on the edge. I don't know what the risk is, so I'd take the precautions in the text message.*
>
> *I would move out regardless because things change, and these things can be highly inaccurate.*

Those who stated that they would modify their actions based on their location at the edge of the hazard area offered comments including:

> *I would still try to relocate, but I would probably not be in such a rush.*
>
> *If you're on the very edge, I think a lot of people would think they're on the safe zone or buffer zone, so it'd be okay if I don't move.*

There was no consensus on which map elements were useful or useless. The accompanying text, shading, scale, format and other elements all had proponents or detractors within the groups. As one participant summed up, "I think people just use maps differently. The way they get their directions, everyone has their own system that they use, but I think including the map doesn't hurt anything."

Suggested improvements to messages and maps. Participants consistently cited formatting, text rearrangement and increased language intensity as ways to improve the messages. Example comments included:

> *… if it could be red font or bold, something that's just easier to read…. just maybe tsunami in big letters….*
>
> *I think you could make the emergency alert text a little bit more prominent, perhaps in all capital letters or make it a different color, because it almost blends into the text. And if you were to just look at it, napping on the beach, something that's bigger and bolder 'emergency' might pop out better and get people's attention.*
>
> *I would move 'tsunami warning' on the top with 'emergency alert' so it's the bold white.*
>
> *I think being more specific about what kind of tsunami or warning would help out. That way you know what you're dealing with. You know how to prepare yourself. And if you don't have any of those options there, you can say, 'Okay, I just need something to stay afloat from the water.'*
>
> *I think the language 'will move on shore' is fairly relaxed. If it says 'will hit shore' it sounds [like] more of an emergency.*

Others asked for county-level descriptions of the hazard area, as is done for some tornado warnings. A few participants suggested reordering content. Said one, "if it said 'Emergency Alert from NOAA' and the first words said 'Tsunami Warning,' I feel like that would be slightly more effective because the first things you see are 'Tsunami Warning.'" Another participant suggested adding language that clarified the severity of the tsunami hazard, "It'd be helpful to include something like 'imminent danger' or 'immediate evacuation' or 'urgent.' Certain words that are only used in certain situations could help clarify because '40 feet' might not sound big, or it might. So, though it's very descriptive [the message], it might not be reaching the audience if they don't understand what that is, which most people don't." One participant recommended the use of hashtags in order to share the message and related updates on social media.

Regarding the tsunami map, participants suggested color-shading the hazard area in terms of relative severity (e.g., red, yellow, green). A few participants noted their confusion about the terms "watch" and "warning." For example, one stated:

> *So, I find that a lot of people, myself included, are confused by the words that are used in some of the warnings. I live in Boulder, and we get a lot of flood watches and flood warnings, and I think people don't know the difference between a watch and a warning. So, this was saying a tsunami warning. I don't know if a warning is more severe than a watch.*

Public education and the WEA service. Participants expressed a range of opinions regarding how to best educate the public about the WEA service—from mobile-based information to traditional forms of advertising. However, one participant explained:

> *I honestly don't think it matters whether people know what it [WEA] is. I think when people get any sort of alert on their phone—emergency alert or Amber Alert—I'm the kind of person that reads it. I don't really care to know what it is.*

Participants voiced a preference for either including app download instructions along with WEA messages or promoting a pre-installed WEA app. One participant explained the benefit of linking a WEA app to an existing, pre-installed app, "I use my weather app almost every day, so I feel like that would be more useful to me to have my weather app and use that for multiple reasons rather than just an emergency alert app that I probably wouldn't use and wouldn't download." Others voiced preferences for traditional public education campaigns, including Public Service Announcements (PSAs), billboards, advertisements, online video pre-roll or even a national "WEA Test Day"—similar to EAS testing. One participant explained:

> *I know when I lived in Durango, they started the Reverse 911 phone call system there, and they had posters up in different places, like the library and public spaces and you could sign up for it. They talked about it on the radio and in newspapers, that kind of stuff. I feel like if there was a campaign or some kind of nation-wide initiative to raise awareness [for WEA], that might be useful.*

6. Conclusions and Future Research

The focus group and experiment research presented in this report provide evidence indicating that if WEAs were to be expanded from their current length (90 characters) to 280 characters, the public would be better able to understand, believe and personalize WEAs, as well as decide on an appropriate course of action. More nuanced findings are presented below. When relevant, the original research reported in this report is compared to the team's prior research on 90-character WEAs, 140-character messages and 1,380-character messages.[12] Finally, recommendations for future research are offered along with the study's limitations.

Message content order. Moving source to the start of the WEA message is optimal; however, the optimal order for WEA message content seems to depend on message length. WEA messages currently use the following order: hazard, location, time, guidance and source. This is different from the optimal order obtained in the team's prior research: source, guidance, hazard, location and time.

For the 280-character messages tested, an alternative order had an advantage in improving the public outcomes tested quantitatively and assessed qualitatively: source, hazard, location, time and guidance. As in the team's prior research, positioning source first yielded optimal outcomes. For the longer 280-character length, however, moving guidance to the end of the message was most effective. This difference may be caused by a recency effect associated with receiving longer messages, which prioritizes information received most recently.

Therefore, (should WEAs be expanded to 280 characters, adopting a different order for the content than the one currently used in WEA auto-generated messages may improve public response outcomes for longer messages. Specifically, messages that order content as "source, hazard, location, time, guidance" may be more effective. Future research is needed on the optimized content order of alert and warning messages longer than 280 characters.

Message source. Local sources may not always be the best sources. Rather, well-known federal sources such as NOAA and the National Weather Service (NWS) can be just as, if not more, effective in some contexts.

[12] Bean, H., Liu, B., Madden, S., Mileti, D., Sutton, J., & Wood, M. (2014). *Comprehensive testing of imminent threat messages for mobile devices*. Retrieved from http://www.firstresponder.gov/TechnologyDocuments/Comprehensive%20Testing%20of%20Imminent%20Threat%20Public%20Messages%20for%20Mobile%20Devices.pdf.

The team's prior research yielded unstable conclusions about the best single message source for a short, 90-character WEA, and led to the conclusion that when only one source can be named, local or familiar sources are best. The results presented here replicated these earlier findings in that well-recognized federal sources, NOAA in particular, were most effective.

Future research in local communities could explore what sources are the most understandable and believable for individual communities. In addition, if it becomes possible that WEA messages can be extended in length beyond 90 characters, research could examine whether an optimized mixed panel of sources would be desirable. Finally, as the public gains a firmer understanding of and exposure to WEAs, research could explore whether source remains important to include first in WEA messages, regardless of length.

Map elements. None of the map elements tested had a statistically significant effect on message outcomes, and focus group participants varied widely in their reactions to the tested maps. Maps can be useful in message personalization, but the role they play varies based on message length.

Specifically, results indicated that the effect of maps on message outcomes varies based on message length. In the absence of maps, the longer the message, the greater the level of understanding, suggesting that longer 1,380-character messages are most effective at motivating public protective actions in response to mobile alerts. Adding maps to shorter 90 and 140-character messages seemed to help increase message understanding, but adding maps to longer messages decreased message understanding. Adding maps to short 90-character messages, on the other hand, may increase response delay, but may help reduce delayed action-taking for longer messages. One possible explanation for the pattern of findings for at least some of the outcomes may be the increased amount of cognitive effort required to processes longer text messages in addition to processing the visual information contained in maps.

Consequently, maps should not be used in WEA messages without further research examining the best way to craft such maps, as well as how they may impact message personalization and other outcomes. Specifically, additional research is needed to determine how to best communicate hazard and receiver location in maps associated with WEA messages. Future research also should examine the extent to which humans are able to process text and visual information in an emergency context.

Relative importance of content elements. The message elements of guidance (what to do and how to do it) and time until impact (how much time people have to take recommended action) play major roles relative to other message elements in impacting the outcomes of public understanding and belief of the protective action recommendation, as well as the ability to decide how to respond. Guidance has a strong impact on individuals' ability to understand a mobile alert message and decide how to respond. Time until impact, additionally, has an impact on the public's belief of mobile alerts. For longer 280-character messages, message source plays a role in increasing message personalization, as well as the ability to decide what to do.

To extend these findings, research is needed on how visualizations can be used to help supplement and enhance the communication of guidance (protective action) in 280-character and longer WEA messages. Research should also further examine the relationship between message-character length and the utility of visual information, such as maps.

Generalizing across hazards. Like shorter messages that are 90 and 140 characters, 280-character messages likely do not contain sufficient information to overcome people's pre-alert and warning event perceptions of different hazards based on any personal experience, perceived risk and knowledge, which may or may not match the event they face. Hence, like 90 and 140-character messages, 280-character messages offer less to help effectively manage public protective action-taking than messages that are 1,380 characters.

Consequently, research is needed to determine the character and intensity of public education that might yield effective public response to 280-character WEA messages. This research could begin with exploring analogous events such as effective public response to earthquake early warnings in Japan, and public radiological impact readiness in America during the Cold War. Research also is needed to determine whether the actual tipping point varies across hazard types. Finally, research is needed during "real-world" events to determine how the public responds to recommended protective actions contained in 280-character messages.

Expanding message content. Should it become possible to expand the length of WEA messages in the future, it would be most important to expand the content areas communicating the hazard (what happened), guidance (what to do about it) and time to impact (when to do it). Expanding these three key message content areas is likely to result in the greatest impact on message outcomes and public warning response.

Therefore, future research should examine whether the greater relative efficacy of providing expanded information about recommended guidance and the time until hazard is consistent across different hazard types. Further research also should examine how to communicate time until event in addition to, or instead of, message expiration time in a way that the public can understand and act upon. Finally, future research should elucidate how to best communicate the guidance (what to do) and the hazard (why to do it), including visualizations.

Effects of links and apps. Including links that display additional general information and using apps that provide more personalized information may be useful strategies for expanding the number of characters available for writing WEA messages and can potentially lead to improved public message outcomes and warning response. For example, we found that level of understanding was significantly higher for individuals who viewed the optimized 280-character WEA message that also included an app containing additional *personalized* information, and for those viewing a message that included an app containing additional *personalized* information plus a map, compared to those who viewed the 280-character optimized WEA message. Level of understanding also was significantly higher for individuals who viewed the optimized 280-character WEA message that also included a link to additional *general* information. Therefore, future research should examine how to best tailor mobile alert messages based on receiver location and other factors to achieve optimal outcomes and also the best way to include future potential links in WEA messages.

Limitations. This research was limited by several factors, including those described here. First, the focus groups and experiments were not conducted in the field during a "real" event, and thus replication is needed in events (as was done in the team's prior research). Second, the research focused on the first WEA message that would be distributed during an event, when in practice multiple WEAs may be distributed during a single event. Consequently, research is needed on how the public reacts to multiple, sequential WEAs. Finally, only three hazards were tested, and additional research is needed on different hazards.

Conclusion. Findings here indicate that while not a magic bullet, 280-character messages clearly are more effective at communicating imminent threats to at-risk public than are the current 90-character WEA messages. In addition, the order of the content contained in an alert – whether it be 90 or 280 characters – remains a critical consideration as does message source. Adding apps and hyperlinks to WEA messages appears promising, but merits additional research. Adding maps to 280-character messages, as tested here, was not promising, but merits additional research. In sum, searching for the "perfect" WEA may be akin to Goldilocks' search for the perfect porridge. Instead, the best course of action may be to optimize WEAs as best as possible, realizing that some members of the public will always seek additional information and clarification from multiple sources.

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Appendix A: Exploratory Focus Groups' Interview Guide, Messages and Maps

Figure 1. Focus Groups' Interview Guide for Apps, Hyperlinks and Maps

Apps and Hyperlinks

(1) Given this scenario, what information do you think you would need in order to be able to protect yourself?
Probe: From where, ideally, would you like to obtain that information (text message, phone app, website, mass media, personal contacts, etc.) and why?
Probe: Do you currently use any disaster preparedness and/or severe weather apps and, if so, which ones and why? If not, why?
(2) If the message included a link to a hyperlink and a webpage, what information would be "critical" for you to have?
Probe: What information would be nice to have?
Probe: What information would be unnecessary?
(3) Does it make a difference whether additional information is provided via a hyperlink versus an app already installed on your phone? Why or why not?
(4) Would you be likely to open a mobile application with additional information and, if so, would you download this app or would you need the government to send it to you with a WEA message?
(5) If you would be unlikely to open a mobile application with additional information, why?
Probe: Under what conditions would you download it?
(6) Would you be likely to download a mobile application with additional information prior to a hazard? Why or why not? (Show example of FEMA app).
(7) Participants were told that in an app, dynamic, changing information based on one's location would be provided. Participants were asked to assess the usefulness of such an application, specifically: (7a) Would you download an app? (7b) When? Why? Why not? (7c) What is your motivation? (7d) Is there any other feedback you have on hyperlinks or apps related to the purpose of this project?

Maps

(1) Do you use maps on your smartphone and, if so, why and if not why?
(2) How would you (and then others) respond to having this map on your smartphone (irrespective of the message contents)?
(3) Which of these maps would you most prefer to have on your smartphone? Why?
(4) How would your decision-making change based on your location within the map and hazard area? (How might others respond?)
(5) Do you think people might be tempted to try to observe the hazard?
(6) Color: Which map is more understandable, believable, and why (grayscale vs. color)?
(7) Detail: Are these maps sufficiently detailed to help you understand their meaning? Why or why not?
(8) Boundary: thick line vs. thick line with shading. Which is more understandable, believable, and why?
(9) What does this location marker mean (multiple styles)?
(10) Note that messages could potentially state: "You are in the area at risk." How does this influence understanding, belief and personalization?
(11) Is there any other feedback you have on the map?

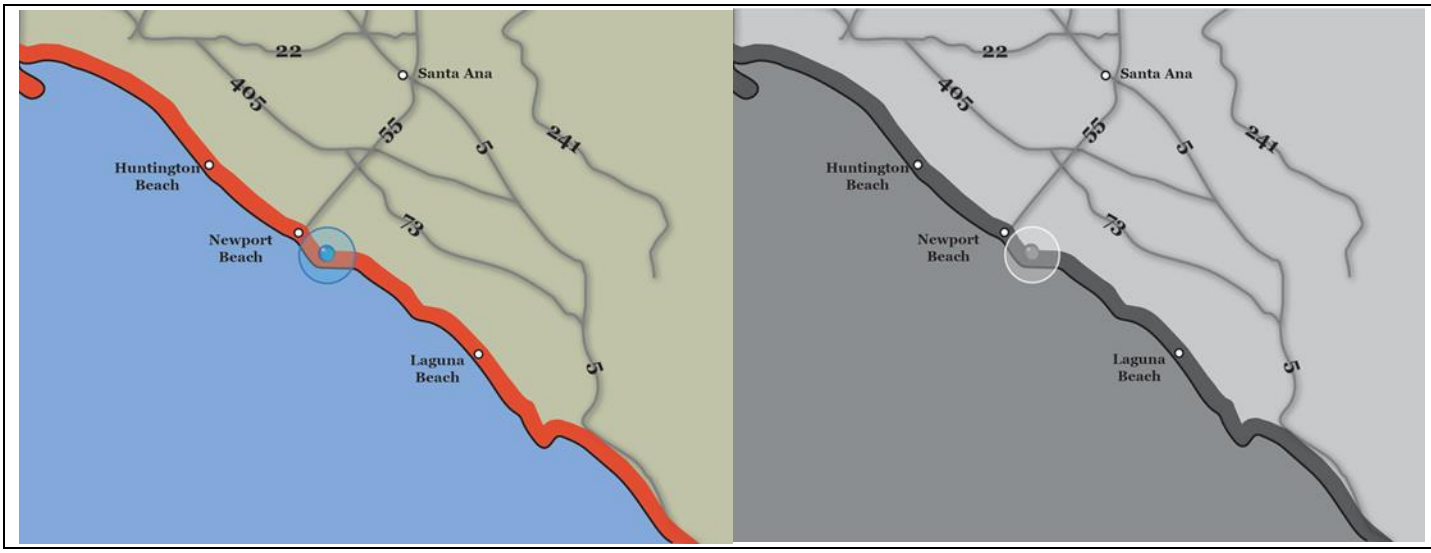
Figure 2. 1,380-character Message and Maps

Message

California Emergency Management Agency. A large earthquake occurred off the coast of Washington state at 1:00 PM PDT. It has generated a tsunami. The first wave will hit the Orange County coastline at 1:45 PM PDT. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. You will be safest if you immediately get to high ground of at least 50 feet or more if you are on or near a beach anywhere in Orange County. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 1:40 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. If you are not in a tsunami impact area, stay away. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep listening to this and other media for more information and official updates. This message expires at 9:00PM PDT.

Maps

The purpose of the Los Angeles area maps are to serve as effective warnings for people who live, work or visit areas where a tsunami warning is in place. We created different versions of the same map, displayed below, to determine which best serves the purpose of alerting the public. The four maps above show the same scenario in different ways. Figures 1 and 2 differ in color versus grayscale. They both show a line inland from the coast, which denotes the area of danger. Figures 3 and 4 also differ in color versus grayscale. The difference here is that the area of danger has been shaded. Each of the four maps includes a marker that notes that location of the person receiving the message. The maps show primary and secondary roads to allow the viewer perspective on their location compared to the event.


22
Santa Ana
405
55
5
241
Huntington Beach
Newport Beach
73
Laguna Beach
5
22
Santa Ana
405
55
5
241
Huntington Beach
Newport Beach
73
Laguna Beach
5

Appendix B: Example Experiment Questionnaire

Experiment Questionnaire Example

This online survey is being conducted as part of a research study. Please read the description below and indicate whether or not you wish to participate.

Why is this study being conducted?
The purpose of this study is to learn how to better communicate with the public using alerts and warnings delivered on cell phones and other mobile devices. The study will explore what people think about different types of warning messages.

What happens if I participate in this study?
If you choose to participate, you will be asked to answer some questions about different warning messages; the questions will take approximately 10 minutes to answer.

What are the possible discomforts or risks?
There are no foreseeable risks to participating in this research.

What are the possible benefits?
There are no benefits to you as a research participant.

Who is paying for this study?
This research is being paid for by the U.S. Department of Homeland Security Science & Technology First Responder Group via a contract administered by the National Consortium for the Study of Terrorism and Responses to Terrorism (START), a DHS-funded Center of Excellence based at the University of Maryland.

Is my participation voluntary?
Your participation is voluntary. You have the right to choose not to participate. If you choose to participate, you have the right to stop at any time. If you refuse or decide to withdraw, you will not lose any benefits or rights to which you are entitled.

Who will see my research information?
Your identity will remain anonymous to the researcher. Your name and contact information will not be stored with your answers. The results from the research may be published. Your identity will not be disclosed and your name will not be linked with your answers in any published reports.

Who do I call if I have questions?
This study is being conducted by Michele Wood, a researcher at the California State University, Fullerton. Michele Wood may be contacted at (657) 278-7330 or mwood@fullerton.edu should you have questions or to report a research-related problem. You may contact the California State University Fullerton IRB at (657) 278-7640 if you have questions or comments about your rights as a study participant.

Consent
If you wish to participate, click "Next" below. If you do not wish to participate, click "Exit this survey" at the upper right corner of your web browser.

By clicking "Next" you give your consent to participate in this research.

1. Do you currently have a working mobile or cell phone, or not?

◯ Yes, I do

◯ No, I do not

Next, assume that you are on vacation in Huntington Beach in Southern California. It's 12:30 in the afternoon. You are home alone, and you just received the following message on your cell phone.

Page 1

Experiment Questionnaire Example

Page 2

Experiment Questionnaire Example

- Respondents: 20%

Page 3

Experiment Questionnaire Example

- Respondents: 20%

Page 3

Experiment Questionnaire Example

- Respondents: 20%

Page 4

Experiment Questionnaire Example

- Respondents: 20%

Page 5

Experiment Questionnaire Example

- Respondents: 20%

Experiment Questionnaire Example

- Respondents: 20%

Answer the following questions using the rating scales provided. You may use any number on the scale.

2. This message made me feel...

	Not at All 1	2	3	4	5	Extremely 6
Shocked	◯	◯	◯	◯	◯	◯
Anxious	◯	◯	◯	◯	◯	◯
Fearful	◯	◯	◯	◯	◯	◯
Sad	◯	◯	◯	◯	◯	◯
Outraged	◯	◯	◯	◯	◯	◯
Nervous	◯	◯	◯	◯	◯	◯
Terror-struck	◯	◯	◯	◯	◯	◯
Scared	◯	◯	◯	◯	◯	◯
Sympathetic	◯	◯	◯	◯	◯	◯
Angry	◯	◯	◯	◯	◯	◯
Tense	◯	◯	◯	◯	◯	◯
Confused	◯	◯	◯	◯	◯	◯

3. The message helped me understand what to do.

Strongly Disagree 1	2	3	4	5	Strongly Agree 6
◯	◯	◯	◯	◯	◯

4. After reading this message, I understand:

	Do not Understand at All 1	2	3	4	5	Fully Understand 6
What happened	◯	◯	◯	◯	◯	◯
The risks	◯	◯	◯	◯	◯	◯
What to do to protect myself	◯	◯	◯	◯	◯	◯
What location is affected	◯	◯	◯	◯	◯	◯
Who the message is from	◯	◯	◯	◯	◯	◯
When I am supposed to take action to protect myself	◯	◯	◯	◯	◯	◯
How long I am supposed to continue taking action to protect myself	◯	◯	◯	◯	◯	◯

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Experiment Questionnaire Example

5. How well do you understand the message?

Do not Understand at All					Fully Understand
1	2	3	4	5	6
◯	◯	◯	◯	◯	◯

6. After reading this message, do you believe that:

	Do not Believe					Believe
	1	2	3	4	5	6
A tsunami is headed your way?	◯	◯	◯	◯	◯	◯
You should immediately move to high ground?	◯	◯	◯	◯	◯	◯
Moving to high ground will make you safer?	◯	◯	◯	◯	◯	◯

7. If I received this message on my cell phone, I would think that:

	Extremely Unlikely					Extremely Likely
	1	2	3	4	5	6
I might become injured	◯	◯	◯	◯	◯	◯
People I know might become injured	◯	◯	◯	◯	◯	◯
People I do not know might become injured	◯	◯	◯	◯	◯	◯
I might die	◯	◯	◯	◯	◯	◯
People I know might die	◯	◯	◯	◯	◯	◯
People I do not know might die	◯	◯	◯	◯	◯	◯
The message was meant for me	◯	◯	◯	◯	◯	◯

8. Use the scale below to show how much you agree or disagree with each statement. You may use any number on the scale.

	Strongly Disagree					Strongly Agree
	1	2	3	4	5	6
The message will **help** me decide what to do.	◯	◯	◯	◯	◯	◯
It will be **easy** to decide what to do.	◯	◯	◯	◯	◯	◯
I will be able to decide what to do **quickly**.	◯	◯	◯	◯	◯	◯
I can decide what to do with **confidence**.	◯	◯	◯	◯	◯	◯

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Experiment Questionnaire Example

9. After receiving the warning message, how likely would you be to look for additional information about each of the following things before beginning to take action? How likely would you be to look for additional information about:

	Extremely Unlikely 1	2	3	4	5	Extremely Likely 6
The size and speed of the tsunami?	◯	◯	◯	◯	◯	◯
The physical consequences of the tsunami?	◯	◯	◯	◯	◯	◯
What geographic area is likely to be affected by the tsunami?	◯	◯	◯	◯	◯	◯
What you should do to protect yourself?	◯	◯	◯	◯	◯	◯
How to take action to protect yourself?	◯	◯	◯	◯	◯	◯
When you should begin taking action to protect yourself?	◯	◯	◯	◯	◯	◯
How long you should continue taking action to protect yourself?	◯	◯	◯	◯	◯	◯
How taking action can reduce your risk?	◯	◯	◯	◯	◯	◯
What your family members are doing about the tsunami?	◯	◯	◯	◯	◯	◯
What your friends are doing about the tsunami?	◯	◯	◯	◯	◯	◯
What people whom you do not know are doing about the tsunami?	◯	◯	◯	◯	◯	◯
The time the warning will end?	◯	◯	◯	◯	◯	◯
Whether the warning message is "real" or "fake"?	◯	◯	◯	◯	◯	◯

10. How likely would you be to take action to protect yourself before confirming the information somewhere else?

Extremely Unlikely 1	2	3	4	5	Extremely Likely 6
◯	◯	◯	◯	◯	◯

Please explain:

11. Based on the message you received, how much time do you believe you have before you should begin taking action?

Hours ☐

Minutes ☐

Seconds ☐

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Experiment Questionnaire Example

12. Would you try to get additional information in any of the following ways? (Check ALL that apply.)

- ☐ Face-to-face from another person (friend, family, co-worker, employee, employer)
- ☐ Television
- ☐ Telephone call - by land line or by cell phone
- ☐ Radio
- ☐ Text message
- ☐ E-mail
- ☐ Twitter
- ☐ Facebook
- ☐ Instagram
- ☐ Pinterest
- ☐ Blogs
- ☐ YouTube
- ☐ Other Internet
- ☐ Some other way
- ☐ NONE OF THESE - I would not try to get additional information

(If you chose "Some other way", please explain)

13. How likely would you be to tell other people about the need to take action?

Very Unlikely					Very Likely
1	2	3	4	5	6
○	○	○	○	○	○

Sometimes text messages include internet hyperlinks in them. "Clicking" on these links redirects your browser to the specified internet address or website. For example, clicking on a link to "www.FEMA.gov" directs you to the FEMA (Federal Emergency Management Agency) website.

The next few questions are about how you would respond if the message you read above also contained an internet link to additional information.

14. If the message above contained an internet link to additional information, how likely is it that you would "click" on the link?

Very Unlikely					Very Likely
1	2	3	4	5	6
○	○	○	○	○	○

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Experiment Questionnaire Example

15. If the message above contained an internet link to additional information, what kind of information would you want to see when you "click" on the link?

	No	Yes
The size and speed of the tsunami	◯	◯
The physical consequences of the tsunami	◯	◯
Where the tsunami will strike and where it won't expressed in words	◯	◯
Where the tsunami will strike and where it won't expressed in a map	◯	◯
What you should do to protect yourself	◯	◯
How much time you have to protect yourself before the tsunami strikes	◯	◯
The time the warning will end	◯	◯
Local media article with more information	◯	◯
Who the message was from	◯	◯
Some other information	◯	◯

(If you chose "Some other information", please specify)

16. If you were to "click" on the internet link to get additional information, how likely is it that you would act on that information without <u>first</u> confirming the information somewhere else?

Very Unlikely					Very Likely	Not Applicable Would not "click" link
1	2	3	4	5	6	
◯	◯	◯	◯	◯	◯	◯

Please explain:

17. If the internet link contained clear instructions about what to do to protect yourself, how likely is it that you would follow those instructions?

Very Unlikely					Very Likely
1	2	3	4	5	6
◯	◯	◯	◯	◯	◯

Please explain:

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Experiment Questionnaire Example

18. How likely would you be to...

	Very unlikely 1	2	3	4	5	Very likely 6
Share the information in the internet link with others before taking action to protect yourself?	◯	◯	◯	◯	◯	◯
Forward the internet link to other people before taking action to protect yourself?	◯	◯	◯	◯	◯	◯
Share the information in the internet link with others after taking action to protect yourself?	◯	◯	◯	◯	◯	◯
Forward the internet link to other people after taking action to protect yourself?	◯	◯	◯	◯	◯	◯

This is the last page about messages.

We would like to know which message is most likely to get you to take action to protect yourself.
Read the following messages, and then place them in rank order.

Message A:
-Orange County Office of Emergency Management. Move now to high ground 50 feet above sea level and at least 6 blocks inland. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Orange County coastal areas until 1:45 PM PST.

Message B:
-Orange County Fire Authority. Move now to high ground 50 feet above sea level and at least 6 blocks inland. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Orange County coastal areas until 1:45 PM PST.

Message C:
-California Office of Emergency Services. Move now to high ground 50 feet above sea level and at least 6 blocks inland. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Orange County coastal areas until 1:45 PM PST.

Message D:
-National Oceanic and Atmospheric Administration. Move now to high ground 50 feet above sea level and at least 6 blocks inland. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Orange County coastal areas until 1:45 PM PST.

Message E:
-National Weather Service. Move now to high ground 50 feet above sea level and at least 6 blocks inland. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Orange County coastal areas until 1:45 PM PST.

19. Place the messages in rank order, where:

1 means MOST likely to get you to take action to protect yourself, and
6 means LEAST likely to get you to take action to protect yourself.

☐	Message A
☐	Message B
☐	Message C
☐	Message D
☐	Message E

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Experiment Questionnaire Example

20. Please explain why you ranked the messages the way you did.

Next we would like to ask you some questions about yourself. You are almost done.

21. Which of the following activities do you do on your mobile or cell phone? (Check all that apply)

- ☐ General internet use (other than using social networking websites)
- ☐ Make or receive phone calls
- ☐ Play games
- ☐ Play music
- ☐ Play podcasts
- ☐ Play videos (other than video games)
- ☐ Purchase products or services
- ☐ Record videos
- ☐ Send or receive emails
- ☐ Send or receive instant messages
- ☐ Send or receive photos
- ☐ Send or receive texts
- ☐ Send or receive videos
- ☐ Take photos
- ☐ Use social networking websites

22. About how comfortable are you using mobile or cell phones?

Extremely **Uncomfortable**					Extremely **Comfortable**
1	2	3	4	5	6
○	○	○	○	○	○

23. Are you male or female?

- ○ Male
- ○ Female

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Experiment Questionnaire Example

24. Which one of these racial/ethnic groups best describes you? Would you say: White; Hispanic or Latino; Black or African American; Asian; Native Hawaiian or other Pacific Islander; American Indian or Alaskan Native; or Other? If you identify with more than one, choose the group you identify with the most.

- ◯ White
- ◯ Hispanic or Latino
- ◯ Black or African-American
- ◯ Asian
- ◯ Native Hawaiian or other Pacific Islander
- ◯ American Indian or Alaskan Native
- ◯ Some other race (please specify)

25. What was your age on your last birthday?

Years

26. What is the highest level of school you have completed or the highest degree you have received?

- ◯ Less than high school degree
- ◯ High school degree or equivalent (e.g., GED)
- ◯ Some college but no degree
- ◯ Associate degree
- ◯ Bachelor degree
- ◯ Graduate degree

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Experiment Questionnaire Example

27. How much total combined money did all members of your household earn in 2012? This includes money from jobs; net income from business, farm, or rent; pensions; dividends; interest; social security payments; and any other money income received by members of your household that are eighteen (18) years of age or older. Please report the total amount of money earned - do not subtract the amount you paid in taxes or any deductions listed on your tax return.

- ◯ $0 to $24,999
- ◯ $25,000 to $49,999
- ◯ $50,000 to $74,999
- ◯ $75,000 to $99,999
- ◯ $100,000 to $124,999
- ◯ $125,000 to $149,999
- ◯ $150,000 to $174,999
- ◯ $175,000 to $199,999
- ◯ $200,000 or More

28. Which of the following categories best describes your employment status?

- ◯ Employed, working 1-39 hours per week
- ◯ Employed, working 40 or more hours per week
- ◯ Not employed, looking for work
- ◯ Not employed, NOT looking for work
- ◯ Retired
- ◯ Disabled, not able to work

29. Are you a student?

- ◯ Yes - Part-time
- ◯ Yes - Full-time
- ◯ No

30. Sometimes disasters happen that affect people living in a community. Please think about the worst disaster you have ever experienced. How much did it affect you?

NO Effect 1	2	3	4	5	A LOT of Effect 6
◯	◯	◯	◯	◯	◯

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Experiment Questionnaire Example

31. Have you ever received an alert or warning message on your cell phone or other mobile device?

- ◯ Yes
- ◯ No

32. Are you subscribed to any cell phone warning services that can send you a text message?

- ◯ Yes
- ◯ No

You are almost done!

33. In what state or U.S. territory do you live?

34. In what California county do you live?

- ◯ Los Angeles County, California
- ◯ San Diego, California
- ◯ Orange County, California
- ◯ Riverside County, California
- ◯ San Bernardino County, California
- ◯ Kern County, California
- ◯ Ventura County, California
- ◯ Santa Barbara County, California
- ◯ San Luis Obispo County, California
- ◯ Imperial County, California

Other (please specify)

35. Do you think there are important questions about warning messages that we should have asked about, or topics we should have covered but didn't in this survey? What else should we have asked about?

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Appendix C: Experimental Statistical Results

Table 1. Experiments: Sample Description

	Experiments							
	1		*2*		*3*		*4*	
	N=409		*N=398*		*N=484*		*N=415*	
Characteristic	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
Gender								
Men	154	38	126	198	228	47	78	50
Women	255	62	272	217	256	53	77	50
Race and/or ethnicity								
Asian	64	16	62	65	88	18	35	23
Hispanic/Latino	64	16	73	64	64	13	37	24
White	239	58	214	245	289	60	42	27
Other	42	10	49	41	43	9	8	5
Age [a]								
Younger (18-54 years)	328	80	341	357	422	87	118	76
Older (55+ years)	81	20	57	58	62	13	37	24
Income								
$0 - $74,999	267	65	253	239	291	60	118	76
$75,000 and more	142	35	145	176	193	40	37	24
Prior Mobile Alert								
Yes	225	55	262	239	295	61	104	73
No	184	45	136	176	189	39	38	27
Live in California								
Yes	398	97	381	404	461	95	155	100
No	11	3	17	11	23	5	0	0

Table 1. (Continued) Experiments: Sample Description

	Experiments							
	5		***6***		***7***		***8***	
	N=439		***N=373***		***N=434***		***N=580***	
Characteristic	***n***	***%***	***n***	***%***	***n***	***%***	***n***	***%***
Gender								
Men	206	47	179	48	211	49	278	48
Women	233	53	194	52	223	52	302	52
Race and/or ethnicity								
Asian	74	17	59	52	70	16	98	17
Hispanic/Latino	70	16	67	18	77	17	107	18
White	248	56	196	16	247	57	314	54
Other	47	11	51	14	40	10	61	11
Age [a]								
Younger (18-54 years)	377	86	321	86	358	82	501	86
Older (55+ years)	62	14	52	14	76	18	79	14
Income								
$0 - $74,999	264	60	230	62	261	60	360	62
$75,000 and more	175	40	143	38	173	40	220	38
Prior Mobile Alert								
Yes	250	57	233	62	263	61	338	58
No	189	43	140	38	171	39	242	42
Live in California								
Yes	422	96	364	98	422	97	553	95
No	17	4	9	2	12	23	27	5

[a] Mean age and (*SD*) for experiment number 1=40.6 (13.3), 2=38.0 (12.9), 3=39.5 (12.6), 4=39.5 (12.4), 5=39.1 (12.6), 6=38.8 (12.5), 7=40.2 (12.9), and 8=38.6 (12.8) years.

Table 2. Experiments: Descriptive Statistics

Scale [a]	Mean	SD	No. of Items	Cronbach's α
Experiment 1 (*N*=409)				
Understanding	4.86	1.04	7	.90
Believing	5.19	1.08	3	.91
Personalizing	4.52	1.24	7	.94
Deciding	4.86	1.15	4	.93
Milling	4.24	1.46	8	.95
Experiment 2 (*N*=398)				
Understanding	4.76	1.09	7	.90
Believing	5.06	1.16	3	.90
Personalizing	4.46	1.23	7	.94
Deciding	4.85	1.19	4	.94
Milling	4.12	1.43	8	.94
Experiment 3 (*N*=484)				
Understanding	4.88	1.07	7	.91
Believing	5.04	1.19	3	.90
Personalizing	4.38	1.25	7	.93
Deciding	4.93	1.11	4	.94
Milling	4.17	1.56	8	.96
Experiment 4 (*N*=415)				
Understanding	4.61	1.09	7	.88
Believing	4.89	1.20	3	.89
Personalizing	4.38	1.17	7	.93
Deciding	4.67	1.21	4	.94
Milling	4.19	1.40	8	.95
Experiment 5 (*N*=439)				
Understanding	4.55	1.12	7	.87
Believing	5.04	1.14	3	.90
Personalizing	4.47	1.25	7	.94
Deciding	4.71	1.29	4	.94
Milling	4.18	1.47	8	.95
Experiment 6 (*N*=373)				
Understanding	4.48	1.08	7	.86
Believing	4.58	1.16	3	.81
Personalizing	4.27	1.20	7	.93
Deciding	4.55	1.18	4	.92
Milling	4.10	1.42	8	.94

Scale [a] *(Continued)*	Mean	SD	No. of Items	Cronbach's α
Experiment 7 (*N*=434)				
Understanding	4.39	1.15	7	.88
Believing	4.82	1.26	3	.89
Personalizing	4.34	1.20	7	.93
Deciding	4.48	1.29	4	.93
Milling	4.30	1.38	8	.94
Experiment 8 (*N*=580)				
Understanding	4.82	1.01	7	.90
Believing	4.97	1.21	3	.92
Personalizing	4.50	1.16	7	.93
Deciding	4.78	1.14	4	.93
Milling	4.04	1.47	8	.96

[a] Items were rated on a 6-point scale, and mean scores were calculated.

Table 3. Experiment 1: Regression of 280-Character Message Outcomes on Message Content Order

Outcome	*Predictor*	*B*	*β*	*p*	*Adjusted R^2*	*F (p)*
Understanding	Source, guidance, hazard, location, time [a, b]	.028	.010	.880	2.2	*2.00 (.038)
	Hazard, location, guidance, time, source	.160	.060	.364		
	Guidance, time, hazard, location, source	.092	.031	.652		
	Source, hazard, location, time, guidance	.431	.159	*.016		
	Guidance, hazard, location, time, source	.321	.117	.076		
	Female [c]	-.144	-.067	.176		
	Asian/Pacific Islander [d]	-.062	-.022	.661		
	Latino	-.386	-.135	*.009		
	Other	-.053	-.015	.769		
Believing	Source, guidance, hazard, location, time	.022	.007	.910	2.1	*1.97 (.041)
	Hazard, location, guidance, time, source	.235	.086	.197		
	Guidance, time, hazard, location, source	.033	.011	.865		
	Source, hazard, location, time, guidance	.400	.143	*.030		
	Guidance, hazard, location, time, source	.134	.048	.472		
	Female	.123	.055	.262		
	Asian/Pacific Islander	-.313	-.108	*.034		
	Latino	-.328	-.111	*.031		
	Other	-.284	-.077	.131		
Personalizing	Source, guidance, hazard, location, time	-.172	-.051	.441	0.6	0.72 (.639)
	Hazard, location, guidance, time, source	.080	.026	.705		
	Guidance, time, hazard, location, source	-.226	-.064	.319		
	Source, hazard, location, time, guidance	-.020	-.006	.927		
	Guidance, hazard, location, time, source	-.065	-.020	.764		
	Female	.066	.026	.605		
	Asian/Pacific Islander	.018	.005	.916		
	Latino	.170	.050	.335		
	Other	-.285	-.067	.192		
Deciding	Source, guidance, hazard, location, time	-.336	-.107	.101	2.5	*2.14 (.025)
	Hazard, location, guidance, time, source	.083	.028	.668		
	Guidance, time, hazard, location, source	-.136	-.042	.513		
	Source, hazard, location, time, guidance	.245	.082	,212		
	Guidance, hazard, location, time, source	.030	.010	.881		
	Female	-.117	-.050	.315		
	Asian/Pacific Islander	-.184	-.060	.240		
	Latino	-.379	-.120	*.019		
	Other	-.261	-.066	.193		
Milling	Source, guidance, hazard, location, time	-.074	-.019	.779	-1.1	0.53 (.856)
	Hazard, location, guidance, time, source	-.061	-.016	.809		
	Guidance, time, hazard, location, source	.115	.028	.668		
	Source, hazard, location, time, guidance	.254	.067	.317		
	Guidance, hazard, location, time, source	.025	.007	.922		

Outcome	Predictor	B	β	p	Adjusted R2	F (p)
	Female	-.011	-.004	.942		
	Asian/Pacific Islander	.084	.021	679		
	Latino	-.012	-.003	.953		
	Other	.372	.074	.151		

[a] Order 2=source, guidance, hazard, location, time; order 3=hazard, location, guidance, time, source; order 4=guidance, time, hazard, location, source; order 5=source, hazard, location, time, guidance; order 6=guidance, hazard, location, time, source.

[b] For order, the reference group was the current auto WEA order (hazard, location, time, guidance, source).

[c] For gender, the reference group was "men."

[d] For race and/or ethnicity, the reference group was "white."

Table 4. Experiment 2: Regression of 280-Character Message Outcomes on Message Source

Outcome	*Predictor*	*B*	*β*	*p*	*Adjusted* R^2	*F (p)*
Understanding	Source – Local, OCFA [a, b]	-.056	-.020	.749	2.0	*1.99 (.046)
	Source – State, OES	.147	.052	.401		
	Source – Federal, NOAA	.428	.162	*.010		
	Source – Federal, NWS	.254	.093	.135		
	Female [c]	-.103	-.044	.382		
	Asian/Pacific Islander [d]	-.314	-.106	*.044		
	Latino	-.172	-.061	.243		
	Other	-.117	-.034	.509		
Believing	Source – Local, OCFA	.142	.048	.447	1.7	1.85 (.067)
	Source – State, OES	.248	.083	.181		
	Source – Federal, NOAA	.326	.116	.065		
	Source – Federal, NWS	.268	.092	.137		
	Female	.103	.041	.412		
	Asian/Pacific Islander	-.398	-.127	*.016		
	Latino	-.148	-.049	.346		
	Other	-.458	-.126	*.015		
Personalizing	Source – Local, OCFA	-.067	-.021	.736	0.2	1.10 (.359)
	Source – State, OES	-.034	-.011	.866		
	Source – Federal, NOAA	.096	.032	.613		
	Source – Federal, NWS	.062	.020	.748		
	Female	.064	.024	.635		
	Asian/Pacific Islander	-.342	-.103	.054		
	Latino	.171	.054	.309		
	Other	-.284	-.074	.158		
Deciding	Source – Local, OCFA	-.133	-.043	.485	3.3	*2.69 (.007)
	Source – State, OES	.130	.042	.492		
	Source – Federal, NOAA	.422	.146	*.020		
	Source – Federal, NWS	.362	.121	.050		
	Female	-.125	-.049	.330		
	Asian/Pacific Islander	-.480	-.149	*.005		
	Latino	-.112	-.036	.485		
	Other	-.207	-.055	.281		
Milling	Source – Local, OCFA	.093	.025	.690	0.2	1.10 (.366)
	Source – State, OES	-.037	-.010	.873		
	Source – Federal, NOAA	-.108	-.031	.625		
	Source – Federal, NWS	-.096	-.027	.669		
	Female	-.051	-.017	.742		
	Asian/Pacific Islander	.397	.102	.055		
	Latino	.458	.124	*.019		
	Other	.312	.070	.183		

[a] Source 2=local-Orange County Fire Authority; source 3=state-California Office of Emergency Services; source 4=federal-National Oceanic and Atmospheric Administration; source 5= federal-National Weather Service.
[b] For source, the reference group was local-Orange County Office of Emergency Management (OEM).
[c] For gender, the reference group was "men."
[d] For race and/or ethnicity, the reference group was "white."

Table 5. Experiment 3: Regression of 280-Character Message Outcomes on Map Features

Outcome	*Predictor*	*B*	*β*	*p*	*Adjusted* R^2	*F (p)*
Personalizing	Area: shading+key [a]	-.199	-.080	.386	0.8	1.38 (.181)
	Marker: Marker+key [b]	-.349	-.140	.125		
	Text: Explanatory Text [c]	-.004	-.002	.987		
	Area X Marker	.276	.091	.397		
	Area X Text	.124	.041	.701		
	Marker X Text	.449	.154	.153		
	Area X Marker X Text	-.212	-.054	.644		
	Female	.270	.108	*.019		
	Asian/Pacific Islander	-.166	-.051	.276		
	Latino	.070	.019	.690		
	Other	-.159	-.036	.440		

[a] The area affected was marked on the map with shading and a key; the reference group was a map with shading only and no key.
[b] The location relative to the area at risk was indicated by a location maker plus a key explaining the meaning of the location marker; the reference group was a map with a marker, but no key.
[c] Additional text indicating that the receiver was in the area affected was included; the reference group received a map without the additional explanatory text.

Table 6a. Experiment 4: Means and Standard Deviations for Message Outcomes by Message Length and Map Inclusion

Outcome	*Length*	*Map*	*Mean*	*SD*	*n*
Understanding	90 characters	No	4.00	1.22	48
		Yes	4.44	1.24	41
	140 characters	No	4.47	1.08	51
		Yes	4.64	0.99	55
	280 characters	No	4.89	0.81	58
		Yes	4.55	1.01	58
	1380 characters	No	5.04	1.00	53
		Yes	4.72	1.14	51
Believing	90 characters	No	4.42	1.18	48
		Yes	5.05	1.10	41
	140 characters	No	4.92	1.01	51
		Yes	5.07	1.08	55
	280 characters	No	4.96	1.20	58
		Yes	5.02	0.99	58
	1380 characters	No	4.90	1.41	53
		Yes	4.75	1.45	51
Personalizing	90 characters	No	4.02	1.27	48
		Yes	4.54	1.26	41
	140 characters	No	4.36	1.09	51
		Yes	4.64	1.00	55
	280 characters	No	4.41	1.07	58
		Yes	4.48	1.06	58
	1380 characters	No	4.29	1.30	53
		Yes	4.24	1.27	51
Deciding	90 characters	No	4.18	1.19	48
		Yes	4.46	1.45	41
	140 characters	No	4.53	1.15	51
		Yes	4.83	1.04	55
	280 characters	No	4.99	1.07	58
		Yes	4.90	1.13	58
	1380 characters	No	4.80	1.31	53
		Yes	4.50	1.26	51
Milling	90 characters	No	3.76	1.43	48
		Yes	4.50	1.45	41
	140 characters	No	4.42	1.11	51
		Yes	4.22	1.36	55
	280 characters	No	4.32	1.28	58
		Yes	4.09	1.58	58
	1380 characters	No	4.28	1.36	53
		Yes	3.96	1.55	51

Table 6b. Experiment 4: Two-Way Analysis of Variance of Message Outcomes by Message Length and Map Inclusion

Outcome	*Source*	*SS*	*df*	*MS*	*F*	*p*
Understanding	Length	22.68	3	7.56	6.74	*<.001
	Map	00.01	1	0.01	0.01	.916
	Length*Map	10.73	3	3.58	3.19	*.024
	Error	456.81	407	1.12		
	Total	9308.74	415			
Believing	Length	4.90	3	1.63	1.15	.327
	Map	3.03	1	3.03	2.14	.144
	Length*Map	7.79	3	2.60	1.84	.140
	Error	576.02	407	1.41		
	Total	10521.78	415			
Personalizing	Length	4.27	3	1.42	1.05	.369
	Map	4.20	1	4.20	3.11	.079
	Length*Map	4.54	3	1.51	1.12	.341
	Error	550.27	407	1.35		
	Total	8511.12	415			
Deciding	Length	19.62	3	6.54	4.56	*.004
	Map	0.23	1	0.23	0.16	.688
	Length*Map	6.44	3	2.15	1.50	.214
	Error	583.26	407	1.43		
	Total	9653.44	415			
Milling	Length	2.56	3	0.85	0.44	.727
	Map	0.00	1	0.00	0.00	.977
	Length*Map	17.28	3	5.76	2.95	*.033
	Error	794.66	407	1.95		
	Total	8111.39	415			

Figure 1. Experiment 4: Understanding by Message Length and Map Inclusion

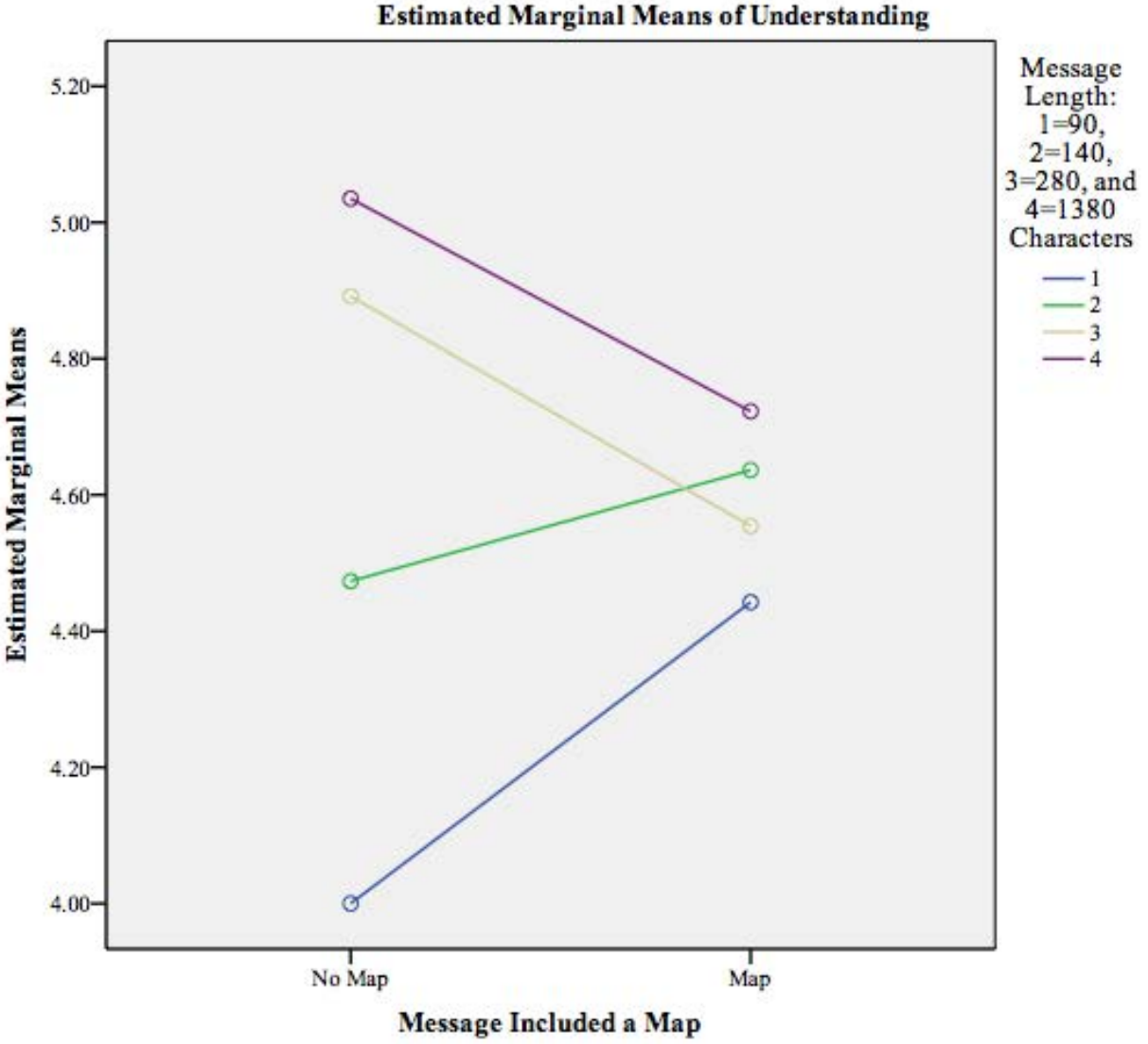


Figure 2. Experiment 4: Belief by Message Length and Map Inclusion

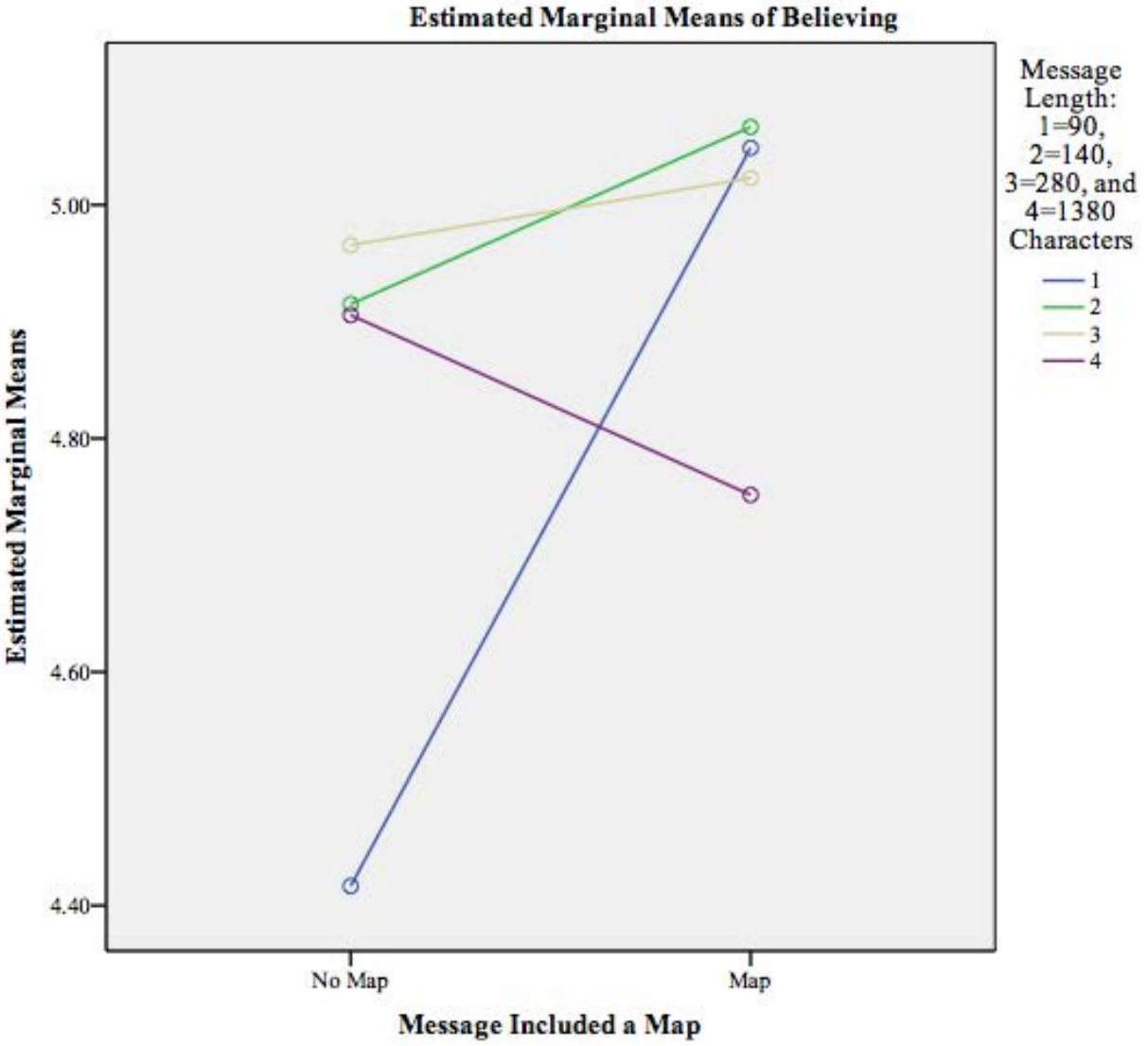


Figure 3. Experiment 4: Personalization by Message Length and Map Inclusion

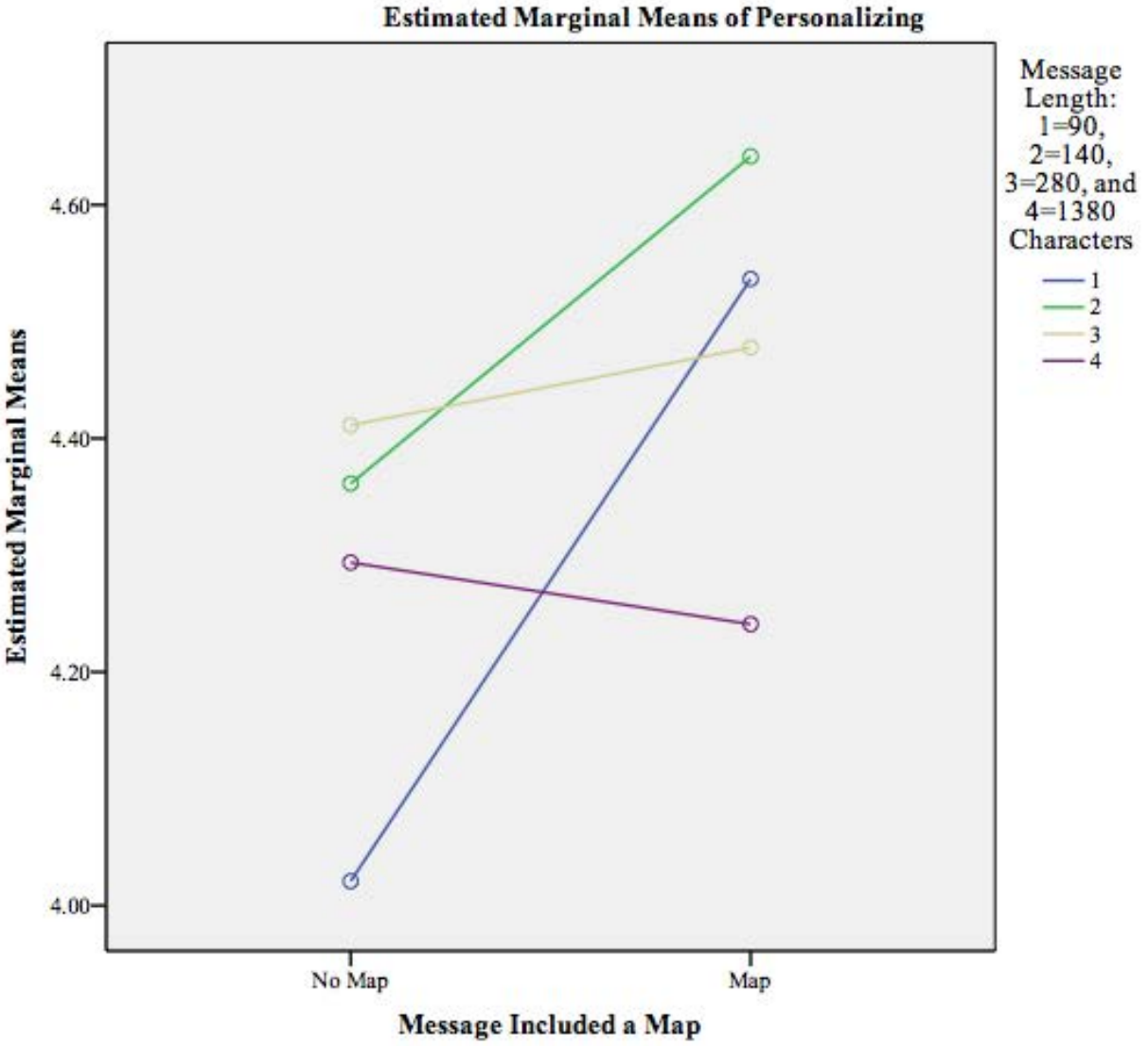


Figure 4. Experiment 4: Deciding by Message Length and Map Inclusion

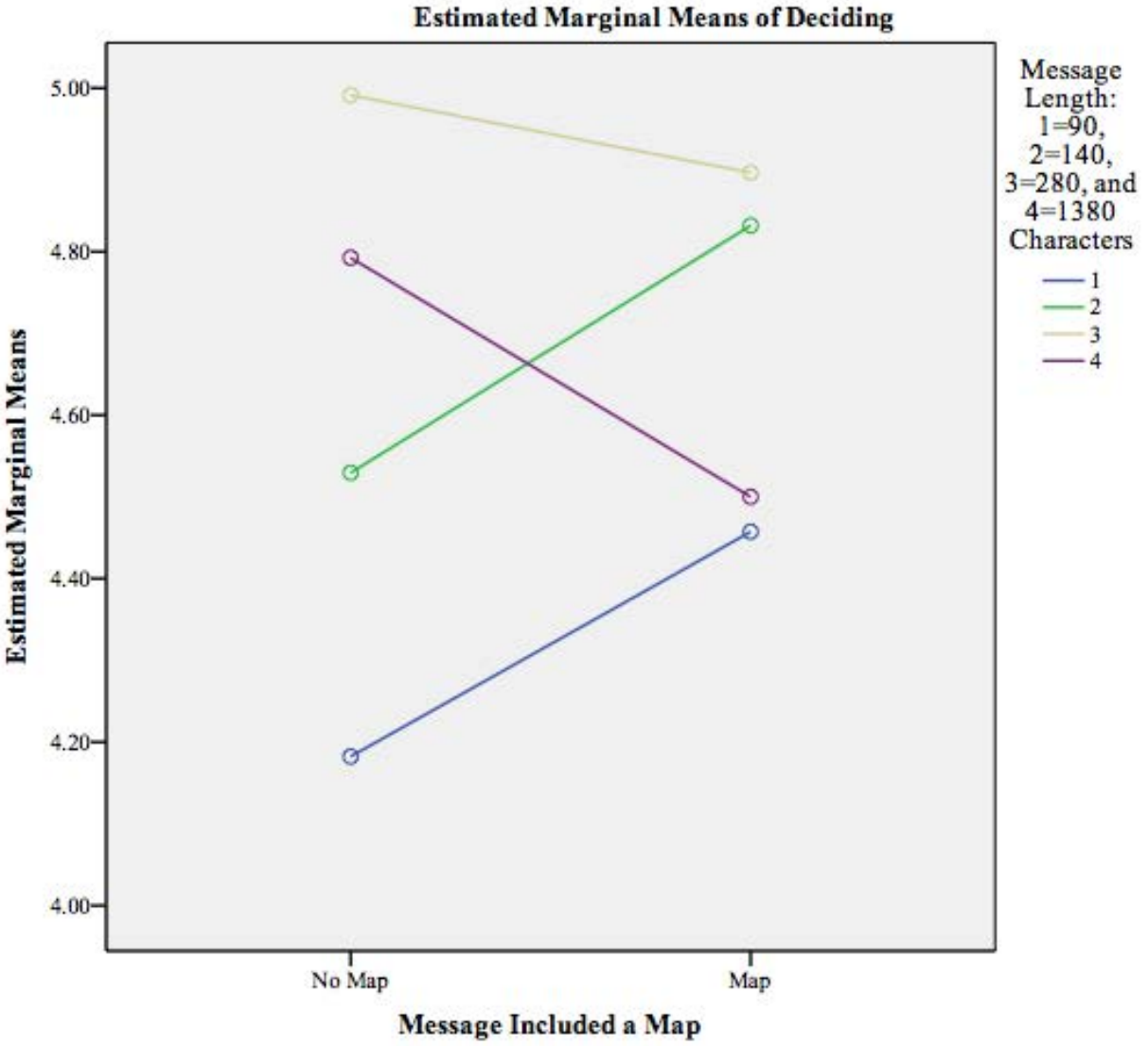


Figure 5. Experiment 4: Milling by Message Length and Map Inclusion

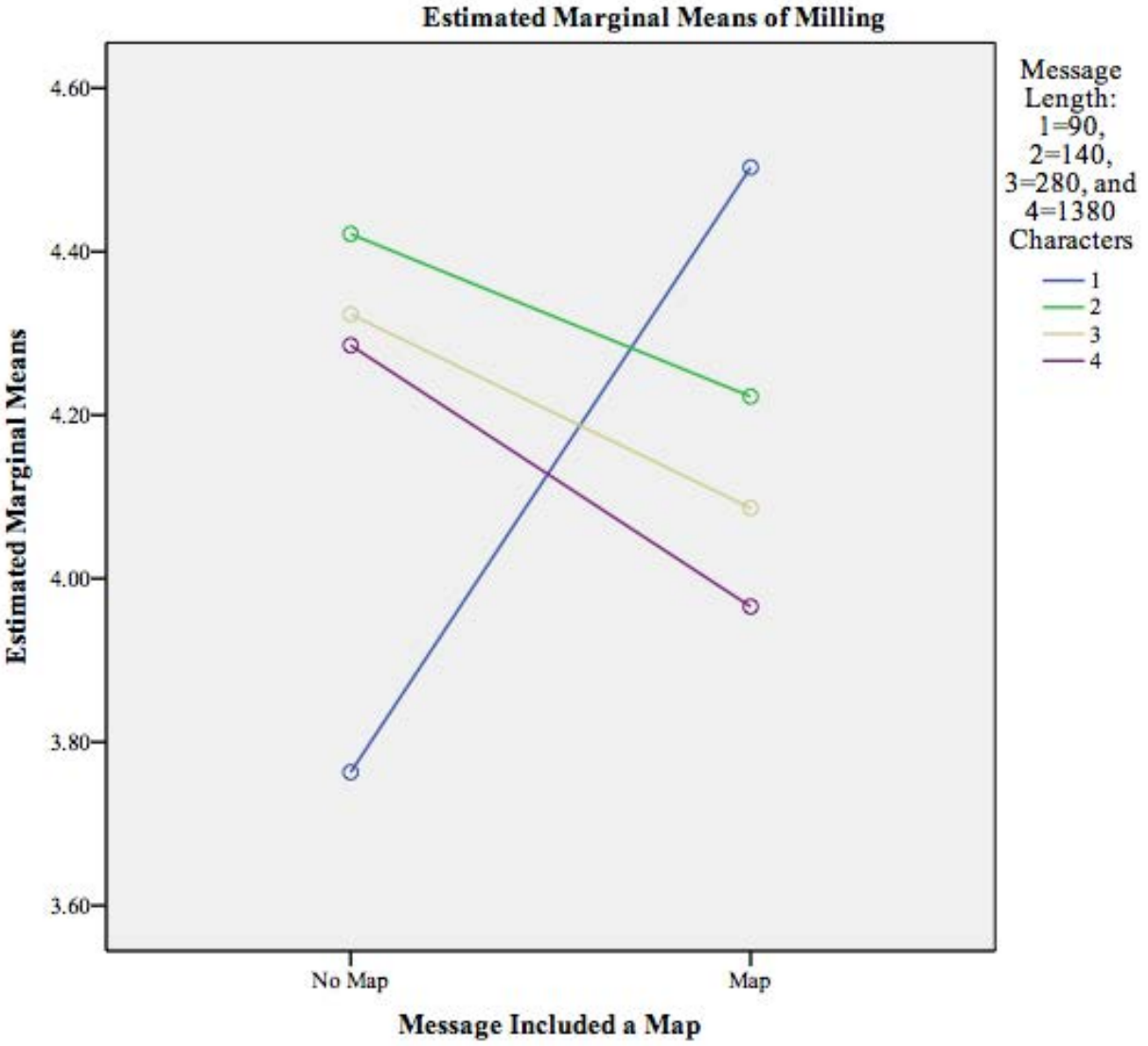


Table 7. Experiment 5: Regression of 280-Character Message Outcomes on Message Elements

Outcome	*Predictor*	*B*	*B*	*p*	*Adjusted R^2 %*	*F (p)*
Understanding	Omitted Hazard[a]	-.209	-.070	.238	1.5	1.76 (.075)
	Omitted Location	-.230	-.081	.177		
	Omitted Guidance	-.546	-.172	*.003		
	Omitted Impact Time	-.449	-.151	*.011		
	Omitted Source	-.178	-.051	.368		
	Female[b]	-.070	-.031	.514		
	Asian/Pacific Islander[c]	.134	.045	.391		
	Latino	-.130	-.043	.367		
	Other	.171	.047	.339		
Believing	Omitted Hazard	-.160	-.053	.376	0.4	1.20 (.239)
	Omitted Location	-.270	-.094	.121		
	Omitted Guidance	-.345	-.107	.068		
	Omitted Impact Time	-.373	-.123	*.040		
	Omitted Source	-.173	-.048	.392		
	Female	.219	.096	*.046		
	Asian/Pacific Islander	-.109	-.036	.474		
	Latino	-.073	-.023	.639		
	Other	.060	.016	.743		
Personalizing	Omitted Hazard	-.146	-.044	.463	0.2	1.08 (.374)
	Omitted Location	-.196	-.062	.305		
	Omitted Guidance	-.164	-.046	.428		
	Omitted Impact Time	-.289	-.087	.146		
	Omitted Source	-.569	-.145	*.011		
	Female	.082	.033	.496		
	Asian/Pacific Islander	.001	.000	.995		
	Latino	.024	.007	.890		
	Other	.255	.063	.205		
Deciding	Omitted Hazard	-.321	-.094	.112	2.8	*2.42 (.011)
	Omitted Location	-.348	-.108	.073		
	Omitted Guidance	-.806	-.220	*<.001		
	Omitted Impact Time	-.436	-.127	*.031		
	Omitted Source	-.569	-.141	*.012		
	Female	.154	.060	.209		
	Asian/Pacific Islander	.144	.042	.394		
	Latino	-.024	-.007	.892		
	Other	.303	.073	.138		
Milling	Omitted Hazard	.368	.094	.111	2.1	*2.05 (.032)
	Omitted Location	-.231	-.063	.298		
	Omitted Guidance	-.076	-.018	.754		
	Omitted Impact Time	.143	.037	.535		
	Omitted Source	-.404	-.088	.117		
	Female	.009	.003	.948		

Asian/Pacific Islander	.385	.098	*.047
Latino	.249	.062	.210
Other	.400	.084	.087

N=439

[a] For omitted element, the reference group was the complete 280-character optimized message.

[b] For gender, the reference group was "men."

[c] For race and/or ethnicity, the reference group was "white."

Table 8. Experiment 6: Regression of 280-Character Message Outcomes on Hazard Type

Outcome	*Predictor*	*B*	*β*	*p*	*Adjusted R^2 %*	*F (p)*
Understanding	Hazard – Tornado[a, b]	-2.75	-.118	.055	1.5	*1.95 (.072)
	Hazard – Flash Flood	-.188	-.084	.171		
	Female [c]	-.051	-.024	.649		
	Asian/Pacific Islander[d]	-.191	-.064	.233		
	Latino	.242	.086	.116		
	Other	.267	.085	.118		
Believing	Hazard – Tornado	-.459	-.183	*.003	3.8	*3.46 (<.002)
	Hazard – Flash Flood	-.420	-.176	*.004		
	Female	.094	.040	.432		
	Asian/Pacific Islander	-.381	-.119	*.026		
	Latino	.199	.066	.222		
	Other	-.087	-.026	.630		
Personalizing	Hazard – Tornado	-.423	-.164	*.007	3.1	*3.01 (.007)
	Hazard – Flash Flood	-.503	-.205	*.001		
	Female	.087	.036	.480		
	Asian/Pacific Islander	-.126	-.038	.473		
	Latino	.286	.092	.089		
	Other	-.094	-.027	.615		
Deciding	Hazard – Tornado	-.246	-.097	.114	1.7	2.04 (.059)
	Hazard – Flash Flood	-.318	-.131	*.033		
	Female	.019	.008	.879		
	Asian/Pacific Islander	-.390	-.120	*.026		
	Latino	.129	.042	.438		
	Other	-.041	-.012	.824		
Milling	Hazard – Tornado	-.076	-.025	.684	1.0	1.62 (.141)
	Hazard – Flash Flood	.191	.065	.289		
	Female	.095	.034	.519		
	Asian/Pacific Islander	.407	.104	.054		
	Latino	.445	.120	*.028		
	Other	.178	.043	.428		

N=373

[a] For hazard type, the reference group was "tsunami."

[b] For gender, the reference group was "men."

[c] For race and/or ethnicity, the reference group was "white."

Table 9. Experiment 7: Regression of 280-Character Message Outcomes on Added Text

Outcome	*Predictor*	*B*	*β*	*p*	*Adjusted R^2*	*F (p)*
Understanding	More Guidance[a, b]	-.098	-.033	.581	4.9	*3.47 (<.001)
	More Hazard	.592	.182	*.002		
	More Time to event	-.206	-.062	.279		
	More Hazard, guidance, time to event	.431	.141	*.018		
	More Source	.045	.015	.804		
	Female[c]	-.126	-.055	.245		
	Asian/Pacific Islander[d]	.143	.046	.348		
	Latino	.344	.115	*.020		
	Other	.019	.005	.922		
Believing	More Guidance	.128	.039	.516	2.5	*2.25 (.018)
	More Hazard	.449	.126	*.032		
	More Time to event	-.209	-.058	.323		
	More Hazard, guidance, time to event	.384	.114	.057		
	More Source	-.180	-.054	.368		
	Female	.184	.073	.125		
	Asian/Pacific Islander	-.069	-.020	.683		
	Latino	.078	.024	.633		
	Other	-.117	-.027	.581		
Personalizing	More Guidance	.235	.076	.217	1.0	1.46 (.159)
	More Hazard	.204	.060	.312		
	More Time to event	.206	.060	.313		
	More Hazard, guidance, time to event	.382	.119	*.050		
	More Source	-.054	-.017	.781		
	Female	.099	.041	.392		
	Asian/Pacific Islander	-.332	-.102	*.042		
	Latino	-.127	-.040	.420		
	Other	-.368	-.088	.074		
Deciding	More Guidance	.041	.012	.836	6.9	*4.55 (<.001)
	More Hazard	.763	.209	*<.001		
	More Time to event	.087	.024	.680		
	More Hazard, guidance, time to event	.751	.219	*<.001		
	More Source	-.114	-.033	.569		
	Female	-.126	-.049	.295		
	Asian/Pacific Islander	.289	.083	.088		
	Latino	.211	.063	.197		
	Other	.281	.063	.187		
Milling	More Guidance	-.052	-.015	.811	-0.1	0.95 (.481)
	More Hazard	.044	.011	.851		

Outcome	Predictor	B	β	p	Adjusted R2	F (p)
	More Time to event	-.009	-.002	.970		
	More Hazard, guidance, time to event	-.389	-.105	.084		
	More Source	-.048	-.013	.828		
	Female	.088	.032	.511		
	Asian/Pacific Islander	-.007	-.002	.971		
	Latino	.217	.060	.235		
	Other	.316	.066	.184		

N=434

[a] For extra text, the reference group was the optimized 90-character WEA from the team's prior research.

[b] For gender, the reference group was "men."

[c] For race and/or ethnicity, the reference group was "white."

Table 10. Experiment 8: Regression of 280-Character Message Outcomes on General Links and Personalized Apps

Outcome	*Predictor*	*B*	*β*	*p*	*Adjusted R^2*	*F (p)*
Understanding	280 char. msg. + general link[a]	.282	.108	*.037	4.2	*3.79 (<.001)
	280 char. msg. + personalized app	.360	.130	*.010		
	280 char. msg. + map	-.052	-.109	.711		
	280 char. msg. + general link + map	.245	.087	.084		
	280 char. msg. + personalized app + map	.324	.119	*.019		
	Female[b]	.209	.104	*.011		
	Asian/Pacific Islander[c]	-.367	-.137	*.001		
	Latino	-.186	-.072	.092		
	Other	-.186	-.057	.179		
Believing	280 char. msg. + general link	-.022	-.007	.889	5.2	*4.55 (<.001)
	280 char. msg. + personalized app	.243	.073	.147		
	280 char. msg. + map	.054	.016	746		
	280 char. msg. + general link + map	-.008	-.002	.960		
	280 char. msg. + personalized app + map	.239	.073	.149		
	Female	.251	.103	*.011		
	Asian/Pacific Islander	-.607	-.188	*<.001		
	Latino	-.260	-.083	*.050		
	Other	-.601	-.152	*<.001		
Personalizing	280 char. msg. + general link	-.187	-.062	.238	-0.3	0.80 (.612)
	280 char. msg. + personalized app	-.024	-.008	.884		
	280 char. msg. + map	-.063	-.020	.700		
	280 char. msg. + general link + map	-.293	-.090	.079		
	280 char. msg. + personalized app + map	-.026	-.008	.874		

Outcome	Predictor	B	β	p	Adjusted R2	F (p)
	Female	.047	.020	.626		
	Asian/Pacific Islander	-.189	-.061	.162		
	Latino	-.034	-.011	.797		
	Other	-.016	-.004	.924		
Deciding	280 char. msg. + general link	.017	.006	.910	2.6	*2.72 (.004)
	280 char. msg. + personalized app	-.027	-.008	.868		
	280 char. msg. + map	-.039	-.013	.806		
	280 char. msg. + general link + map	.105	.033	.519		
	280 char. msg. + personalized app + map	.147	.048	.352		
	Female	.123	.054	.194		
	Asian/Pacific Islander	-.570	-.187	*<.001		
	Latino	-.286	-.097	*.024		
	Other	-.243	-.065	.126		
Milling	280 char. msg. + general link	-.187	-.049	.350	0.8	1.54 (.130)
	280 char. msg. + personalized app	.177	.044	.394		
	280 char. msg. + map	.026	.006	.902		
	280 char. msg. + general link + map	.098	.024	.643		
	280 char. msg. + personalized app + map	-.139	-.035	.498		
	Female	-.176	-.060	.150		
	Asian/Pacific Islander	.243	.062	.154		
	Latino	.404	.106	*.014		
	Other	.284	.059	.167		

N=580

a The reference group was the optimized 280-character WEA message, with no map.

b For gender, the reference group was “men.”

c For race and/or ethnicity, the reference group was “white.”

Appendix D: Study Design

Table 1. Experiment 1 Design: Effect of Content Order

	Condition					
Message Feature	**1**	**2**	**3**	**4**	**5**	**6**
Length 1 – 90 characters						
Length 2 – 140 characters						
Length 3 – 280 characters	X	X	X	X	X	X
Length 4 – 1,380 characters						
Order 1 – source, guidance, hazard, location, time (optim.)	X					
Order 2 – hazard, location, time, guidance, source (WEA)		X				
Order 3 – hazard, location, guidance, time, source			X			
Order 4 – guidance, time, hazard, location, source				X		
Order 5 – source, hazard, location, time, guidance					X	
Order 6 – guidance, hazard, location, time, source						X
Source 1 – local (OCOEM)						
Source 2 – local (OCFA)						
Source 3 – state (CAL OES)	X	X	X	X	X	X
Source 4 – federal (NWS)						
Source 5 – federal (WEA)						
Maps 1 – absent	X	X	X	X	X	X

N=409

Table 2. Experiment 2 Design: Effect of Message Source

	Condition				
Message Feature	**1**	**2**	**3**	**4**	**5**
Length 1 – 90 characters					
Length 2 – 140 characters					
Length 3 – 280 characters	X	X	X	X	X
Length 4 – 1,380 characters					
Order 1 – source, guidance, hazard, location, time					
Order 2 – hazard, location, time, guidance, source (WEA)	X	X	X	X	X
Order 3 – hazard, location, guidance, time, source					
Order 4 – guidance, time, hazard, location, source					
Order 5 – source, hazard, location, time, guidance					
Order 6 – guidance, hazard, location, time, source					
Source 1 – local (OCOEM)	X				
Source 2 – local (OCFA)[13]		X			
Source 3 – state (CAL OES)			X		
Source 4 – federal (NOAA)				X	
Source 5 – federal (NWS)					X
Maps 1 – absent	X	X	X	X	X

N=398

[13] We replaced "CDC" with "OCFA-Orange County Fire Authority" based on findings from the team's prior research.

Table 3. Experiment 3 Design: Effect of Different Map Features

	Condition								
Message Feature	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Length 1 – 90 characters									
Length 2 – 140 characters									
Length 3 – 280 characters	X	X	X	X	X	X	X	X	X
Length 4 – 1,380 characters									
Order – Best	X	X	X	X	X	X	X	X	X
Source – Best (single)	X	X	X	X	X	X	X	X	X
Map 1 – No map	X								
Map 2 – Area Affected - Shading		X	X	X	X				
Map 3 – Area Affected - Shading + Key[14]						X	X	X	X
Map 4 – Marker – Dot		X	X			X	X		
Map 5 – Marker – Dot + Key[15]				X	X			X	X
Map 6 – Text – No additional text		X		X		X		X	
Map 7 – Text – Additional text[16]			X		X		X		X
Map 8 – Some Detail[17]		X	X	X	X	X	X	X	X
Map 9 – Color - Color[18]		X	X	X	X	X	X	X	X

N=484

[14] Key = "Shading indicates the area at risk."

[15] Key = "Dot indicates your location."

[16] Text = "You are in an area at risk."

[17] We held the amount of map detail constant based on standard practice and belief that too much detail confuses map-readers.

[18] We held color constant based on strong and consistent focus group findings, which support industry practice.

Table 4. Experiment 4 Design: Effect of Amount of Information Provided—Length (90, 140, 280, 1,380 Characters) and Maps

	Condition							
Message Feature[19]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Length 1 – 90 characters	X				X			
Length 2 – 140 characters		X				X		
Length 3 – 280 characters			X				X	
Length 4 – 1,380 characters				X				X
Map 1 – no map	X	X	X	X				
Map 2 – best map					X	X	X	X

N=415

[19] We used the message order from the results of experiment 1.

Table 5. Experiment 5 Design: Effect of Different Message Elements

	Condition					
Message Feature	**1**	**2**	**3**	**4**	**5**	**6**
Length 1 – 90 characters						
Length 2 – 140 characters						
Length 3 – 280 characters	X	X	X	X	X	X
Length 4 – 1,380 characters						
Order – best	X	X	X	X	X	X
Source – best (single)	X	X	X	X	X	X
Element 1 – guidance	X		X	X	X	X
Element 2 – hazard	X	X		X	X	X
Element 3 – time to impact	X	X	X		X	X
Element 4 – guidance + hazard + time to impact	X	X	X	X		X
Element 5 – source	X	X	X	X	X	

N=439

Table 6. Experiment 6 Design: Effect of Hazard Type

	Condition		
Message Feature	**1**	**2**	**3**
Length 1 – 90 characters			
Length 2 – 140 characters			
Length 3 – 280 characters	X	X	X
Length 4 – 1,380 characters			
Order – best	X	X	X
Source – best (single)	X	X	X
Hazard 1 – tsunami	X		
Hazard 2 – tornado		X	
Hazard 3 – flash flood			X

N=373

Table 7. Experiment 7 Design: Effect of Spending the Additional 190 Characters on Different Message Elements

	Condition					
Message Feature	**1**	**2**	**3**	**4**	**5**	**6**
Length 1 – 90 characters						
Length 2 – 140 characters						
Length 3 – 280 characters	X	X	X	X	X	X
Length 4 – 1,380 characters						
Order – best	X	X	X	X	X	X
Source – best (single)	X	X	X	X	X	X
Text 1 – 90-characters WEA (optimized order, source)	X					
Text 2 – More about guidance		X				
Text 3 – More about hazard			X			
Text 4 – More about time to event				X		
Text 5 – More about hazard + guidance + time to event					X	
Text 6 – More about source (text not acronym)						X

N=434

Table 8. Experiment 8 Design: Effect of Including Links and Apps (general text, personalized text, maps)

Message Feature	Condition					
	1	**2**	**3**	**4**	**5**	**6**
Length 1 – 90 characters						
Length 2 – 140 characters						
Length 3 – 280 characters	X	X	X	X	X	X
Length 4 – 1,380 characters						
Order – best						
Source – best (single)						
Map – no map	X	X	X			
Map – best map				X	X	X
Link 1 – no extra text	X			X		
Link 2 – general extra text "Link"		X			X	
Link 3 – personalized extra text "App"			X			X

N=580

Table 9. Text of Messages Tested in Experiments

COLOR CODE KEY: source guidance hazard location termination time impact time.

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
1	1	Order 1 – source, guidance, hazard, location, time	Source: California Office of Emergency Services. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Location: Orange County coastal areas termination time: until 1:45 PM PST.	268
1	2	Order 2 – hazard, location, time, guidance, source (automated WEA order, CONTROL)	Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland. Source: -California Office of Emergency Services.	268
1	3	Order 3 – hazard, location, guidance, time, source	Hazard:Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland termination time: until 1:45 PM PST. Source:-California Office of Emergency Services.	268
1	4	Order 4 – guidance, time, hazard, location, source	Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland termination time: until 1:45 PM PST. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas. Source: -California Office of Emergency Services.	268
1	5	Order 5 – source, hazard, location, time, guidance	Source: -California Office of Emergency Services. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	268
1	6	Order 6 – guidance, hazard, location, time, source	Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST. Source: -California Office of Emergency Services.	268

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
2	1	Source level 1 – local, OEM (CONTROL)	Source: -Orange County Office of Emergency Management. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST.	273
2	2	Source level 2 – local, OCFA	Source: -Orange County Fire Authority. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST.	257
2	3	Source level 3 – state, OES	Source: -California Office of Emergency Services. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST.	268
2	4	Source level 4 – federal, NOAA	Source: -National Oceanic and Atmospheric Administration. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST.	276
2	5	Source level 5 – federal, NWS	Source: -National Weather Service. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST.	253
3	1	No map (Control)	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
3	2	Map: Area: Shading Marker: Dot Add. Text: No	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas Termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276
3	3	Map: Area: Shading Marker: Dot Add. Text: Yes	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas Termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276
3	4	Map: Area: Shading Marker: Dot+Key Add. Text: No	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276
3	5	Map: Area: Shading Marker: Dot+Key Add. Text: Yes	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas Termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276
3	6	Map: Area: Shading+Key Marker: Dot Add. Text: No	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas Termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276
3	7	Map: Area: Shading+Key Marker: Dot Add. Text: Yes	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas Termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276
3	8	Map: Area: Shading+Key Marker: Dot+Key Add. Text: No	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas Termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
3	9	Map: Area: Shading+Key Marker: Dot+Key Add. Text: Yes	Source: National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in location: Orange County coastal areas Termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level and at least 6 blocks inland.	276
4	1	Length – 90, no map	Source: NOAA. Hazard: Tsunami Warning location: in this area Termination time: until 9:00 PM PDT. Guidance: Evacuate now.	66
4	2	Length – 140, no map	Source: NOAA. Hazard: Tsunami Warning. Waves over 40 feet above sea level location: in Orange County. Termination time: Warning expires 9:00 PM PDT. Guidance: Evacuate to higher ground now.	135
4	3	Length – 280, no map	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people location: in this area. Termination time: The first wave will arrive by 1:45 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland, or go to the 3rd floor of a building.	274
4	4	Length – 1380, no map	Source: NOAA. Hazard: A large earthquake occurred off the coast of Washington state at 1:00 PM PDT. It has generated a tsunami. The first wave will hit the Orange County coastline at 1:45 PM PDT. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. location: This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. Termination time: This message expires at 9:00PM PDT. Guidance: You will be safest if you immediately get to high ground of at least 50 feet or more if you are on or near a beach anywhere in Orange County. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 1:40 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. If you are not in a tsunami impact area, stay away. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep listening to this and other media for more information and official updates.	1,306
4	5	Length – 90, map	Source: NOAA. Hazard: Tsunami Warning location: in this area Termination time: until 9:00 PM PDT. Guidance: Evacuate now.	66

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
4	6	Length – 140, map	Source: NOAA. Hazard: Tsunami Warning. Waves over 40 feet above sea level location: in Orange County. Termination time: Warning expires 9:00 PM PDT. Guidance: Evacuate to higher ground now.	135
4	7	Length – 280, map	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people location: in this area. Termination time: The first wave will arrive by 1:45 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland, or go to the 3rd floor of a building.	274
4	8	Length – 1380, map	Source: NOAA. Hazard: A large earthquake occurred off the coast of Washington state at 1:00 PM PDT. It has generated a tsunami. The first wave will hit the Orange County coastline at 1:45 PM PDT. Hazard: Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. location: This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. Termination time: This message expires at 9:00PM PDT. Guidance: You will be safest if you immediately get to high ground of at least 50 feet or more if you are on or near a beach anywhere in Orange County. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 1:40 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. If you are not in a tsunami impact area, stay away. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep listening to this and other media for more information and official updates.	1,306
5	1	All elements included	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people location: in this area. The first wave will arrive by 1:45 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.	280
5	2	Omit: Hazard specificity and Impact Consequences	Source: NOAA. location: In this area. The first wave will arrive by 1:45 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.	181

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
5	3	Omit: Location specificity	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people. The first wave will arrive by 1:45 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.	278
5	4	Omit: Guidance specificity	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people location: in this area. The first wave will arrive by 1:45 PM PDT.	267
5	5	Omit: Time until Impact	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people location: in this area. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.	237
5	6	Omit: Source	Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people location: in this area. The first wave will arrive by 1:45 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.	274
6	1	Tsunami – 280	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people location: in this area. The first wave will arrive by 1:00 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.	278
6	2	Tornado – 280	Source: NOAA. Hazard: Tornado Warning. Flying debris will damage or destroy homes and could kill people. A funnel cloud was reported location: in this area. A tornado may develop at any time. Guidance: Move now to a storm shelter, safe room or interior room on the lower floor of a sturdy building. Avoid windows.	277
6	3	Flash Flood – 280	Source: NOAA. Hazard: Flash Flood Warning. Flood waters will rise rapidly and could destroy property and injure or kill people location: in this area. Flash flooding is expected to begin at any time. Guidance: Move now to higher ground. If you come to a closed or flooded road, turn around. Do not try to cross.	275

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
7	1	New text 1 – No new text: WEA message with optimized order and source. (control)[20]	Source: -NOAA. Hazard: Tsunami Warning location: in this area Termination time: until 1:45 PM PST. Guidance: Take shelter now.	72
7	2	New text 2 – More about hazard	Source: -NOAA. Hazard: Tsunami Warning. A large earthquake occurred and generated a tsunami. Tsunami waves destroy property and lives. Multiple waves will move onshore quickly and reach 40 feet above sea level location: in this area Termination time: until 1:45 PM PST. Guidance: Take shelter now.	243
7	3	New text 3 – More about guidance	Source: –NOAA. Hazard: Tsunami Warning location: in this area Termination time: until 1:45 PM PST. Guidance: Move now to high ground 50 feet above sea level. Go at least 6 blocks inland. If you cannot reach high ground, go to the 3rd floor of a building and stay until you hear the all clear.	238
7	4	New text 4 – More about time to event	Source: -NOAA. Hazard: Tsunami Warning location: in this area. The first of multiple waves will arrive by 1:45 PM PDT. Guidance: Take shelter now.	110
7	5	New text 5 – More about hazard + guidance + time to event	Source: -NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people location: in this area. The first wave will arrive by 1:45 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland, or go to the 3rd floor of a building.	275
7	6	New text 6 – More about source (text not acronym)	Source: -National Oceanic and Atmospheric Administration. Hazard: Tsunami Warning location: in this area Termination time: until 1:45 PM PST. Guidance: Take shelter now.	115

[20] For experiment 3, the messages will incorporate the optimal source and order of message contents based on experiments 1 and 2.

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
8	1	280 Tsunami alert No extra text No map	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people location: in this area. The first wave will arrive by 1:00 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.	280
8	2	280 Tsunami alert Link/Static extra text No map	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people location: in this area. The first wave will arrive by 1:00 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher. PLUS LINK TO THE FOLLOWING TEXT: Source: NOAA. Hazard: A large earthquake occurred off the coast of Washington state at 12:25 PM PDT. It has generated a tsunami. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. location: This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. The first wave will hit the Orange County coastline at 1:00 PM PDT. Termination time: This message expires at 9:00PM PDT. Guidance: You will be safest if you immediately get to high ground of at least 50 feet or more if you are on or near a beach anywhere in Orange County. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 12:55 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. If you are not in a tsunami impact area, stay away. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep following this and other media for more information and official updates.	

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
8	3	280 Tsunami alert App/Dynamic extra text No map	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people location: in this area. The first wave will arrive by 1:00 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher. PLUS LINK TO THE FOLLOWING APP: Source: NOAA. Hazard: A large earthquake occurred off the coast of Washington state at 12:25 PM PDT. It has generated a tsunami. According to the mobile app, you are in Orange County now, in the area at risk. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. location: This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. The first wave will hit the Orange County coastline at 1:00 PM PDT. Termination time: This message expires at 9:00PM PDT. Guidance: Based on your current location, you will be safest if you immediately get to high ground of at least 50 feet or more. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 12:55 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep following this and other media for more information and official updates.	
8	4	280 Tsunami alert No extra text Map	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people location: in this area. The first wave will arrive by 1:00 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.	

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
8	5	280 Tsunami alert Link/Static extra text Map	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people location: in this area. The first wave will arrive by 1:00 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher. PLUS LINK TO THE FOLLOWING TEXT: **Emergency Alert – Official Link** Source: NOAA. Hazard: A large earthquake occurred off the coast of Washington state at 12:25 PM PDT. It has generated a tsunami. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. location: This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. The first wave will hit the Orange County coastline at 1:00 PM PDT. Termination time: This message expires at 9:00PM PDT. Guidance: You will be safest if you immediately get to high ground of at least 50 feet or more if you are on or near a beach anywhere in Orange County. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 12:55 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. If you are not in a tsunami impact area, stay away. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep following this and other media for more information and official updates.	

Exp. #	Cond. #	Condition Description	Message Text	Length (Char.)
8	6	280 Tsunami alert App/Dynamic extra text Map	Source: NOAA. Hazard: Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people location: in this area. The first wave will arrive by 1:00 PM PDT. Guidance: Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher. PLUS LINK TO THE FOLLOWING APP SCREEN: **Emergency Alert – Personalized Mobile App** Source: NOAA. Hazard: A large earthquake occurred off the coast of Washington state at 12:25 PM PDT. It has generated a tsunami. According to the mobile app, you are in Orange County now, in the area at risk. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. location: This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. The first wave will hit the Orange County coastline at 1:00 PM PDT. Termination time: This message expires at 9:00PM PDT. Guidance: Based on your current location, you will be safest if you immediately get to high ground of at least 50 feet or more. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 12:55 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep following this and other media for more information and official updates.	

Figure 1. Experiment 1 Messages

Condition 1

Condition 2

Condition 3

Condition 4

Condition 5

Condition 6

Figure 2. Experiment 2 Messages

Condition 1

Condition 2

Condition 3

Condition 4


12:30
Saturday, June 27
Emergency Alert
-National Weather Service. Move now to high ground 50 feet above sea level and at least 6 blocks inland. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Orange County coastal areas until 1:45 PM PST.

Condition 5

Figure 3. Experiment 3 Messages

Condition 1

Condition 2

Condition 3

Condition 4

Condition 5

Condition 6

Figure 4. Experiment 4 Messages

Condition 1

Condition 2

Condition 3

Condition 4

Condition 5

Condition 6

Condition 7

Condition 8


12:30
Saturday, June 27
Emergency Alert
-National Oceanic and Atmospheric Administration. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and injure people in Orange County coastal areas until 1:45 PM PST. Move now to high ground 50 feet above sea level and at least 6 blocks inland.
Huntington Beach
You are in an area at risk.
Shading indicates area at risk.
Dot indicates your location.

Condition 9

Figure 5. Experiment 5 Messages

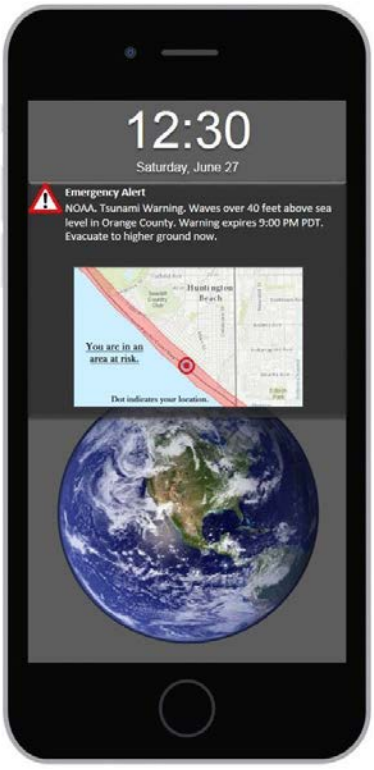
Condition 1

Condition 2

Condition 3

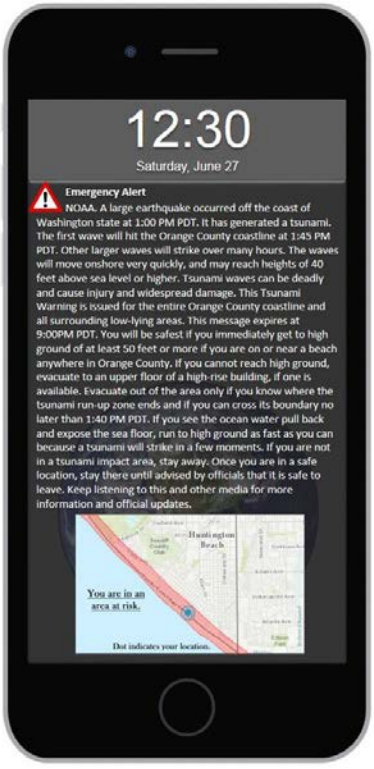
Condition 4

Condition 5



Condition 6

Condition 7



Condition 8

Figure 6. Experiment 6 Messages

Condition 1

Condition 2

Condition 3

Condition 4

Condition 5

Condition 6

Figure 7. Experiment 7 Messages

Condition 1

Condition 2

Condition 3

Figure 8. Experiment 8 Messages

Condition 1


12:30
Saturday, June 27
Emergency Alert
NOAA. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people in this area. The first wave will arrive by 1:00 PM PDT. Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.
For more information, click on the link:
www.WEA.CA15avf235.gov
12:30
Saturday, June 27
Emergency Alert – Link
NOAA. A large earthquake occurred off the coast of Washington state at 12:25 PM PDT. It has generated a tsunami. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. The first wave will hit the Orange County coastline at 1:00 PM PDT. This message expires at 9:00PM PDT. You will be safest if you immediately get to high ground of at least 50 feet or more if you are on or near a beach anywhere in Orange County. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 12:55 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. If you are not in a tsunami impact area, stay away. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep following this and other media for more information and official updates.

Condition 2


12:30
Saturday, June 27
Emergency Alert
NOAA. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people in this area. The first wave will arrive by 1:00 PM PDT. Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.
For more information, start your personalized app:
www.WEA.CA15avf235.gov
12:30
Saturday, June 27
Emergency Alert – Personalized Mobile App
NOAA. A large earthquake occurred off the coast of Washington state at 12:25 PM PDT. It has generated a tsunami. According to the mobile app, you are in Orange County now, in the area at risk. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. The first wave will hit the Orange County coastline at 1:00 PM PDT. This message expires at 9:00PM PDT. Based on your current location, you will be safest if you immediately get to high ground of at least 50 feet or more. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 12:55 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep following this and other media for more information and official updates.

Condition 3


12:30
Saturday, June 27
Emergency Alert
NOAA. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people in this area. The first wave will arrive by 1:00 PM PDT. Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.
Huntington Beach
You are in an area at risk.
Dot indicates your location.

Condition 4


12:30
Saturday, June 27
Emergency Alert
NOAA. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people in this area. The first wave will arrive by 1:00 PM PDT. Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.
For more information, click on the link:
www.WEA.CA15avf235.gov
12:30
Saturday, June 27
Emergency Alert – Link
NOAA. A large earthquake occurred off the coast of Washington state at 12:25 PM PDT. It has generated a tsunami. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. The first wave will hit the Orange County coastline at 1:00 PM PDT. This message expires at 9:00PM PDT. You will be safest if you immediately get to high ground of at least 50 feet or more if you are on or near a beach anywhere in Orange County. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 12:55 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. If you are not in a tsunami impact area, stay away. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep following this and other media for more information and official updates.
Huntington Beach
You are in an area at risk.
Dot indicates your location.

Condition 5


12:30
Saturday, June 27
Emergency Alert
NOAA. Tsunami Warning. 40ft waves will move onshore quickly and could destroy property and kill people in this area. The first wave will arrive by 1:00 PM PDT. Move now to high ground 50 feet above sea level, at least 6 blocks inland or to the 3rd floor of a building or higher.
For more information, start your personalized app:
www.WEA.CA15avf235.gov
12:30
Saturday, June 27
Emergency Alert – Personalized Mobile App
NOAA. A large earthquake occurred off the coast of Washington state at 12:25 PM PDT. It has generated a tsunami. According to the mobile app, you are in Orange County now, in the area at risk. Other larger waves will strike over many hours. The waves will move onshore very quickly, and may reach heights of 40 feet above sea level or higher. Tsunami waves can be deadly and cause injury and widespread damage. This Tsunami Warning is issued for the entire Orange County coastline and all surrounding low-lying areas. The first wave will hit the Orange County coastline at 1:00 PM PDT. This message expires at 9:00PM PDT. Based on your current location, you will be safest if you immediately get to high ground of at least 50 feet or more. If you cannot reach high ground, evacuate to an upper floor of a high-rise building, if one is available. Evacuate out of the area only if you know where the tsunami run-up zone ends and if you can cross its boundary no later than 12:55 PM PDT. If you see the ocean water pull back and expose the sea floor, run to high ground as fast as you can because a tsunami will strike in a few moments. Once you are in a safe location, stay there until advised by officials that it is safe to leave. Keep following this and other media for more information and official updates.
Huntington Beach
You are in an area at risk.
Dot indicates your location.

Condition 6

Appendix E: Confirmatory Focus Groups Interview Guide and Messages

Figure 1. Focus Groups' Interview Guide for Optimized 280-Character WEA Messages

TSUNAMI MESSAGE

(1) Does this 280-character message, by itself, provide you sufficient information to protect yourself? Why or why not?

Probe: What do you think would be the consequence of receiving an insufficient message? What would you do if the message were insufficient?

(2) What additional information, if any do you think you would need in order to be able to protect yourself?

Probe: From where, ideally, would you like to obtain that information (text message, phone app, website, mass media, personal contacts, etc.)?

(3) Do you think that you *could* follow the guidance provided in this message? Why? Why not?

(4) Do you think that you *would* follow the guidance provided in this message? Why? Why not?

(5) What are the best words to use in this 280-character WEA message in order to motivate you to take action? Why?

(6a) Would you be likely to open a hyperlink to additional information? (6b) Would you be likely to open or mobile application with additional information? (6c) Would you download this app yourself or would you need the government to send it to you with a WEA message?

(7) In a hyperlink or app, what additional information, beyond types already mentioned, would be critical for you to have?

(8a) Do you prefer a map? (8b) Is a map necessary? (8c) Are you confused by the map? (8d) If you are confused by the map, what would you do next? (8e) What would you do if you were near the edge of the hazard area indicated on the map? (8f) Please go through the map and star and circle helpful and unhelpful elements.

(9) Is there anything else you would like to add about how the message could be improved?

(10) What would be the best way for you to learn more about WEAs?

OTHER HAZARDS: TORNADO AND FLOOD

(1) Does this 280-character WEA message, by itself, provide you sufficient information to protect yourself? Why or why not?

(2) What additional information, if any do you think you would need in order to be able to protect yourself?

(3) Do you think that you *could* follow the guidance provided in this message? Why? Why not?

(4) Do you think that you *would* follow the guidance provided in this message? Why? Why not?

(5) What are the best words to use in this 280-character WEA message in order to motivate you to take action? Why?

Figure 2. Mock WEA Messages Presented to Focus Group Participants

Tsunami Message

Tsunami Message with Map

Tornado Message

Flood Message